100 YEARS OF ANIMAL HEALTH 1884-1984

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100 YEARS OF ANIMAL HEALTH

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PREFACE

This history of the Bureau of Animal Industry (BAI) and successor agencies was undertaken as part of the centennial of the establishment of the Bureau on May 29, 1984. The BAI Centennial Task Force provided general direction and support for this effort. The task force was headed by E. C. Sharmon and Larry Mark as co-chairmen without whose enthusiastic leadership the project would not have been initiated. The Task Force consisted of representatives from Animal and Plant Health Inspection Service (APHIS), Agricultural Research Service (ARS), Food Safety and Inspection Service (FSIS), and the Economic Research Service (ERS).

Each chapter reflects the attitude and viewpoint of the respective author. A select list of references is included at the end of each chapter. A number of persons from the concerned agencies, to whom we extend our thanks, have reviewed each chapter.

Formation of the Bureau marked the first organized efforts to control or eradicate animal diseases and perform regulatory activities. It provided a mechanism for cooperation between Federal and State governments, private veterinary practitioners, and producers.

From a small beginning centered on a single campaign against contagious bovine pleuropneumonia, the Bureau soon expanded its efforts into all aspects of animal agriculture—production and genetics research, and meat inspection.

Only five men served as chiefs of the Bureau of Animal Industry from its organization in 1884 to its consolidation into other agencies in 1953. Brief biographies of these chiefs follow the act establishing the Bureau.

EDITORIAL COMMITTEE
Vivian Wiser, ERS
Larry Mark, APHIS
H. Graham Purchase, ARS

H. R. No. 3967.

Forty-eighth

Congress of the United States, At the First Session,

Begun and held at the CITY OF WASHINGTON, in the DISTRICT OF COLUMBIA, on Monday, the third day of December, eighteen hundred and eighty-three

AN ACT

For the establishment of a Bureau of Animal Industry, to prevent the exportation of diseased cattle, and to provide means for the suppression and extirpation of pleuro-pneumonia and other contagious diseases among domestic animals.

Be it enacted *by the Senate and House of Representatives of the United States of America in Congress assembled,*

That the Commissioner of Agriculture shall organize in his Department a Bureau of Animal Industry, and shall appoint a Chief thereof, who shall be a competent veterinary surgeon, and whose duty it shall be to investigate and report upon the condition of the domestic animals of the United States, their protection and use, and also inquire into and report the causes of contagious, infectious, and communicable diseases among them, and the means for the prevention and cure of the same, and to collect such information on these subjects as shall be valuable to the agricultural and commercial interests of the country; and the Commissioner of Agriculture is hereby authorized to employ a force sufficient for this purpose, not to exceed twenty persons at any one time. The salary of the Chief of said Bureau shall be three thousand dollars per annum; and the Commissioner shall appoint a clerk for said Bureau, with a salary of one thousand five hundred dollars per annum.

Sec. 2. That the Commissioner of Agriculture is authorized to appoint two competent agents, who shall be practical stock-raisers or experienced business men familiar with questions pertaining to commercial transactions in live stock, whose duty it shall be, under the instructions of the Commissioner of Agriculture, to examine and report upon the best methods of treating, transporting, and caring for animals, and the means to be adopted for the suppression and extirpation of contagious pleuro-pneumonia, and to provide against the spread of other dangerous contagious, infectious, and communicable diseases. The compensation of said agents shall be at the rate of ten dollars per diem, with all necessary expenses, while engaged in the actual performance of their duties under this act, when absent from

THE ACT ESTABLISHING THE BUREAU OF ANIMAL INDUSTRY

this usual place of business or residence as such agent.

Sec. 3. That it shall be the duty of the Commissioner of Agriculture to prepare such rules and regulations as he may deem necessary for the speedy and effectual suppression and extirpation of said diseases, and to certify such rules and regulations to the executive authority of each State and Territory, and invite said authorities to co-operate in the execution and enforcement of this act. Whenever the plans and methods of the Commissioner of Agriculture shall be accepted by any State or Territory in which pleuro-pneumonia or other contagious, infectious, or communicable disease is declared to exist, or such State or Territory shall have adopted plans and methods for the suppression and extirpation of said diseases, and such plans and methods shall be accepted by the Commissioner of Agriculture, and whenever the governor of a State or other properly constituted authorities signify their readiness to co-operate for the extinction of any contagious, infectious, or communicable disease in conformity with the provisions of this act, the Commissioner of Agriculture is hereby authorized to expend so much of the money appropriated by this act as may be necessary in such investigations, and in such disinfection and quarantine measures as may be necessary to prevent the spread of the disease from one State or Territory into another.

Sec. 4. That in order to promote the exportation of live stock from the United States the Commissioner of Agriculture shall make special investigation as to the existence of pleuro-pneumonia, or any contagious, infectious, or communicable disease, along the dividing-lines between the United States and foreign countries, and along the lines of transportation from all parts of the United States to ports from which live stock are exported, and make report of the results of such investigation to the Secretary of the Treasury, who shall, from time to time, establish such regulations concerning the exportation and transportation of live stock as the results of said investigations may require.

Sec. 5. That to prevent the exportation from any port of the United States to any port in a foreign country of live stock affected with any contagious, infectious, or communicable disease, and especially pleuro-pneumonia, the Secretary of the Treasury be, and he is hereby, authorized to take such steps and adopt such

measures, not inconsistent with the provisions of this act, as he may deem necessary.
Sec. 6. That no railroad company within the United States, or the owners or masters of any steam or sailing or other vessel or boat, shall receive for transportation or transport, from one State or Territory to another, or from any State into the District of Columbia, or from the District into any State, any live stock affected with any contagious, infectious, or communicable disease, and especially the disease known as pleuro-pneumonia; nor shall any person, company, or corporation deliver for such transportation to any railroad company, or master or owner of any boat or vessel, any live stock, knowing them to be affected with any contagious, infectious, or communicable disease; nor shall any person, company, or corporation drive on foot or transport in private conveyance from one State or Territory to another, or from any State into the District of Columbia, or from the District into any State, any live stock, knowing them to be affected with any contagious, infectious, or communicable disease, and especially the disease known as pleuro-pneumonia: Provided, That the so-called splenetic or Texas fever shall not be considered a contagious, infectious, or communicable disease within the meaning of sections four, five, six and seven of this act, as to cattle being transported by rail to market for slaughter, when the same are unloaded only to be fed and watered in lots on the way thereto.

Sec. 7. That it shall be the duty of the Commissioner of Agriculture to notify, in writing, the proper officials or agents of any railroad, steamboat, or other transportation company doing business in or through any infected locality, and by publication in such newspapers as he may select, of the existence of said contagion; and any person or persons operating any such railroad, or master or owner of any boat or vessel, or owner or custodian of or person having control over such cattle or other live stock within such infected district, who shall knowingly violate the provisions of section six of this act shall be guilty of a misdemeanor, and, upon conviction, shall be punished by a fine of not less than one hundred nor more than five thousand dollars, or by imprisonment for not more than one year, or by both such fine and imprisonment.

Sec. 8. That whenever any contagious, infectious, or communicable disease affecting domestic animals, and especially the disease known as pleuro-pneumonia, shall

be brought into or shall break out in the District of Columbia, it shall be the duty of the Commissioners of said District to take measures to suppress the same promptly and to prevent the same from spreading; and for this purpose the said Commissioners are hereby empowered to order and require that any premises farm, or farms where such disease exists, or has existed, be put in quarantine; to order all or any animals coming into the District to be detained at any place or places for the purpose of inspection and examination; to prescribe regulations for and to require the destruction of animals affected with contagious infectious, or communicable disease, and for the proper disposition of their hides and carcasses; to prescribe regulations for disinfection, and such other regulations as they may deem necessary to prevent infection or contagion being communicated, and shall report to the Commissioner of Agriculture whatever they may do in pursuance of the provisions of this section.

Sec. 9. That it shall be the duty of the several United States district attorneys to prosecute all violations of this act which shall be brought to their notice or knowledge by any person making the complaint under oath; and the same shall be heard before any district or circuit court of the United State or Territorial court holden within the district in which the violation of this act has been committed.

Sec. 10. That the sum of one hundred ~~and fifty~~ thousand dollars, to be immediately available, or so much thereof as may be necessary, is hereby appropriated, out of any moneys in the Treasury not otherwise appropriated, to carry into effect the provisions of this act.

Sec. 11. That the Commissioner of Agriculture shall report annually to Congress, at the commencement of each session, a list of the names of all persons employed, an itemized statement of all expenditures under this act, and full particulars of the means adopted and carried into effect for the suppression of contagious, infectious, or communicable diseases among domestic animals.

John G. Carlisle

Speaker of the House of Representatives

Approved May 29 1884

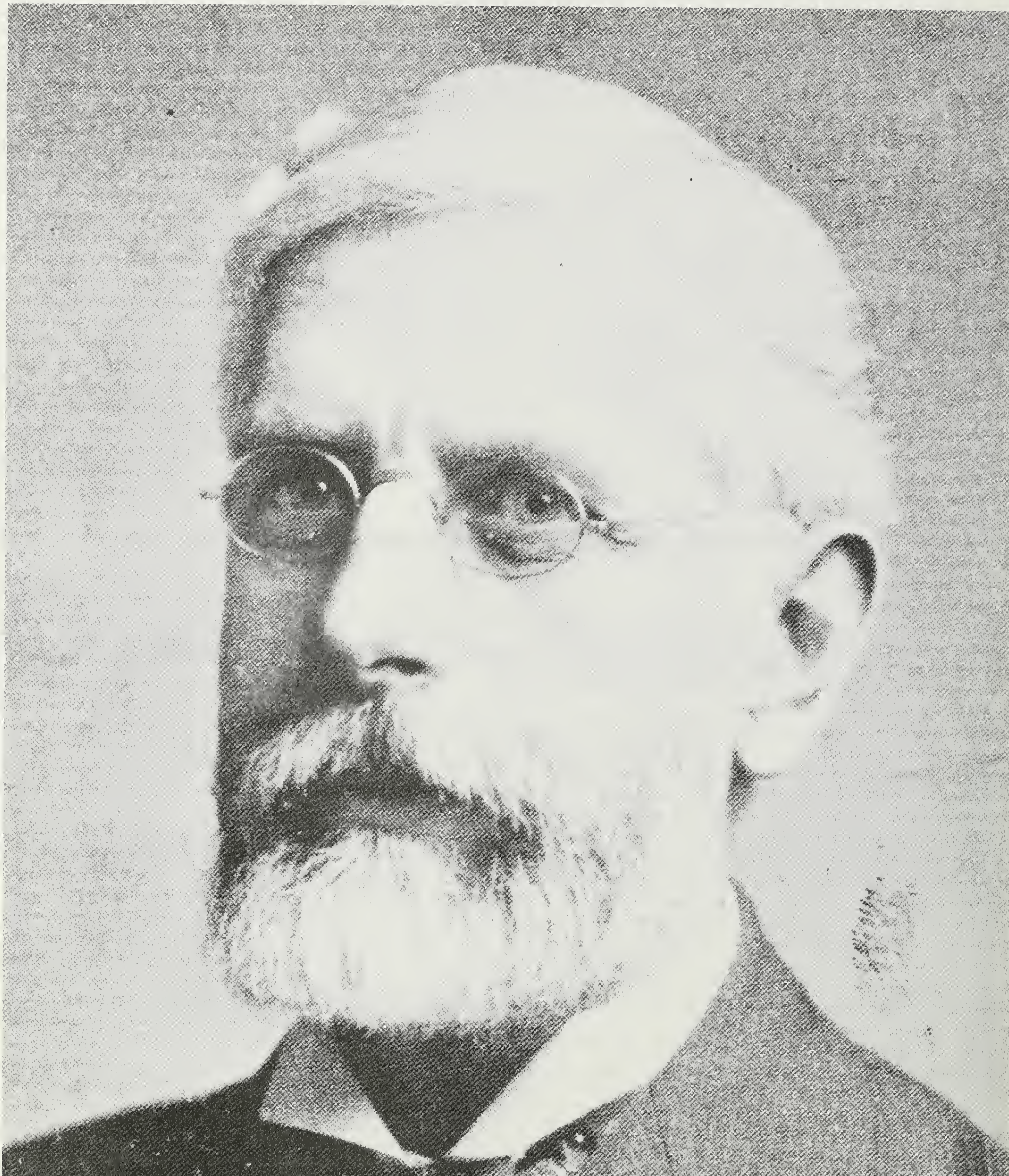
Chester A. Arthur

Geo. F. Edmunds

President of the Senate pro tempore.

CHIEFS OF THE BUREAU OF ANIMAL INDUSTRY
1884 - 1953

Five men served as chiefs of the Bureau of Animal Industry from its establishment until its absorption into the Agricultural Research Service. They provided a strength of leadership that such continuity fostered.



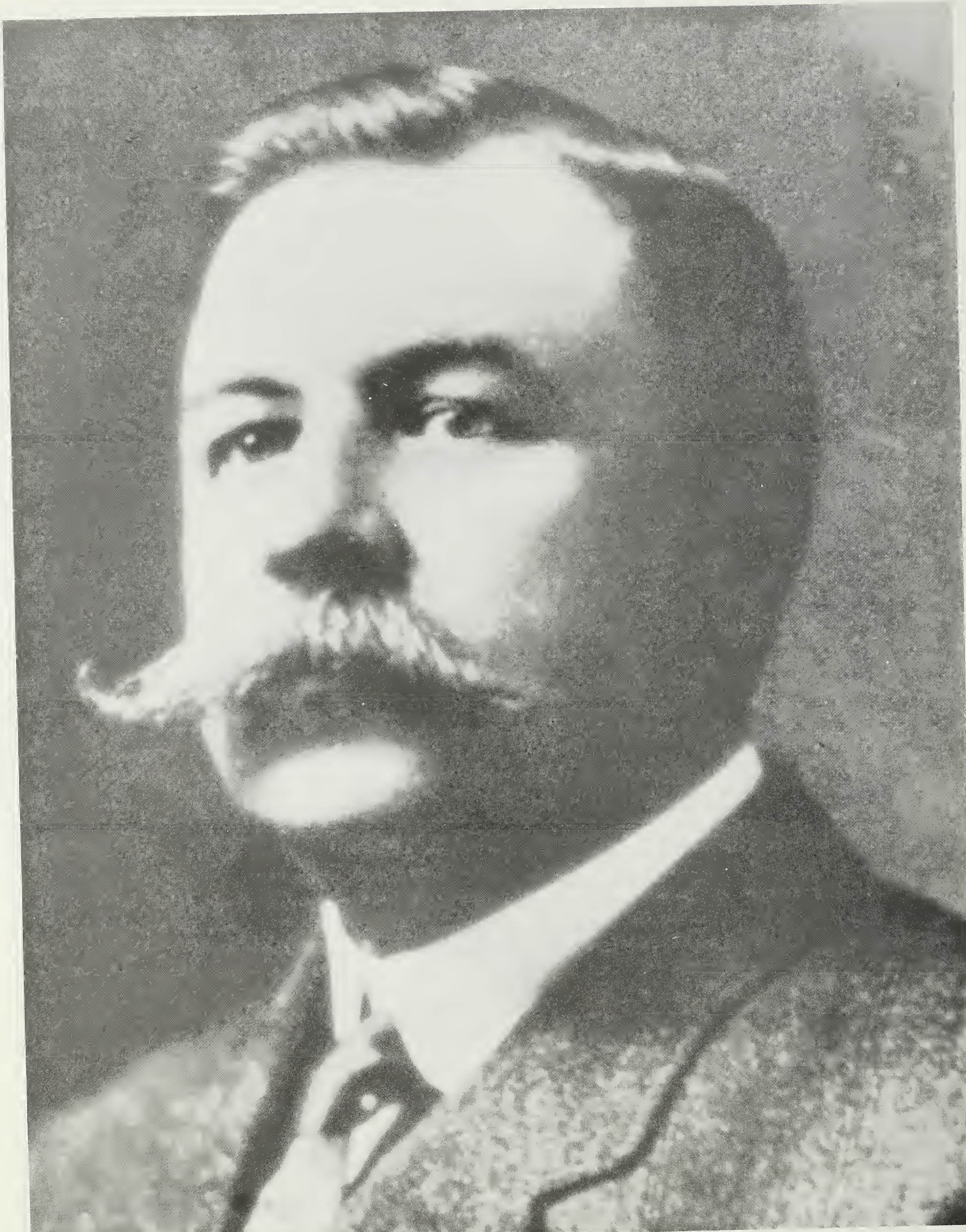
Daniel E. Salmon
1884 - 1905

Daniel E. Salmon was born July 23, 1850, in Mt. Olive, New Jersey, and died on August 30, 1914. He received a Doctor of Veterinary Medicine degree in 1876 from Cornell University, where he studied under James Law. He also took an active part in the early investigations of animal diseases for the U.S. Department of Agriculture (USDA).

Salmon had worked intermittently for USDA from as early as 1878 on reports on various animal diseases. In 1883, he was appointed chief of the new Veterinary Division in USDA, which the following year became the Bureau of Animal Industry. However, some veterinarians had attempted to have the activities added to those of the National Board of Health or the Treasury Cattle Commission.

As head of a new agency Salmon was a target. Then, as the powers of that Bureau were extended to quarantine and/or slaughter of livestock, he was subjected to more criticism. In 1892, he became involved in the so-called National Veterinary College in Washington, D.C., a nongovernment endeavor to provide trained personnel for the Bureau. However, other veterinary schools were extremely critical of the project and forced its closure. Then too, there was the whole question of the enforcement of the meat inspection program. He walked a tight rope in his relations with the large processors, that, in the end, resulted in his leaving the Bureau just before the more stringent meat inspection act was passed in 1906.

His extensive writings reflected his research on animal diseases and the activities of his Bureau involving them, as well as early work with animal breeding and meat inspection. He actively participated in various professional organizations and was an associate member of several European organizations. From 1906 to 1912 he served as Director of the National Veterinary School in Montevideo, Uruguay. On his return to the United States, he began work in a hog cholera serum production plant where a recurrence of a pulmonary disease proved fatal.



Alonzo E. Melvin
1905 - 1917

Dr. Melvin served as chief of the Bureau of Animal Industry (BAI) from 1905 until his death, December 7, 1917. He was born in Sterling, Illinois, October 28, 1862. He received a Doctorate of Veterinary Science from the Chicago Veterinary College in 1886 and started working for the new Bureau of Animal Industry. He was one of the veterinarians sent to Liverpool, England, in 1890 to inspect animals and vessels coming from the United States to determine their condition in view of the many charges by European countries of widespread diseases among imports. Subsequently, he was in charge of meat inspection in Chicago, and from 1895 to 1899 he was chief of the Inspection Division. He was assistant chief of the Bureau from 1899 to 1905.

His 12 years of service in charge of BAI were years of momentous change. In 1906, the meat inspection work was expanded following the publication of Upton Sinclair's book, *The Jungle*. Work with diseases, their treatment, quarantine, and eradiction were greatly expanded. He was also active in promoting dipping of animals for disease control. Thus, advances were made in control of tick fever, tuberculosis, sheep scabies, hog cholera, dourine, and contagious abortion. Because of his support, the system was adopted of accrediting herds free of tuberculosis. In writing of him several years later Edward N. Wentworth reported: "His ability as an administrator, his sterling qualities as a man, his nobility of character, his gentle and sympathetic nature, and his loyalty to the Bureau endeared him to all. . . .His 12 years in the Bureau of Animal Industry were indeed years of big undertakings, and his constructive recognition of the nation's problems contributed largely. . . to the relatively healthy status of American livestock."

John R. Mohler
1917 - 1943

On July 31, 1943, John R. Mohler retired after 46 years of service with the Bureau of Animal Industry. He had come, in 1897, as a veterinary inspector working on animal diseases. Subsequently, he became involved in meat inspection and then chief of the Pathological Division in 1901, assistant chief of BAI in 1914, and chief of the Bureau in 1917. His 26 years in this position was the longest of any chief of that agency.

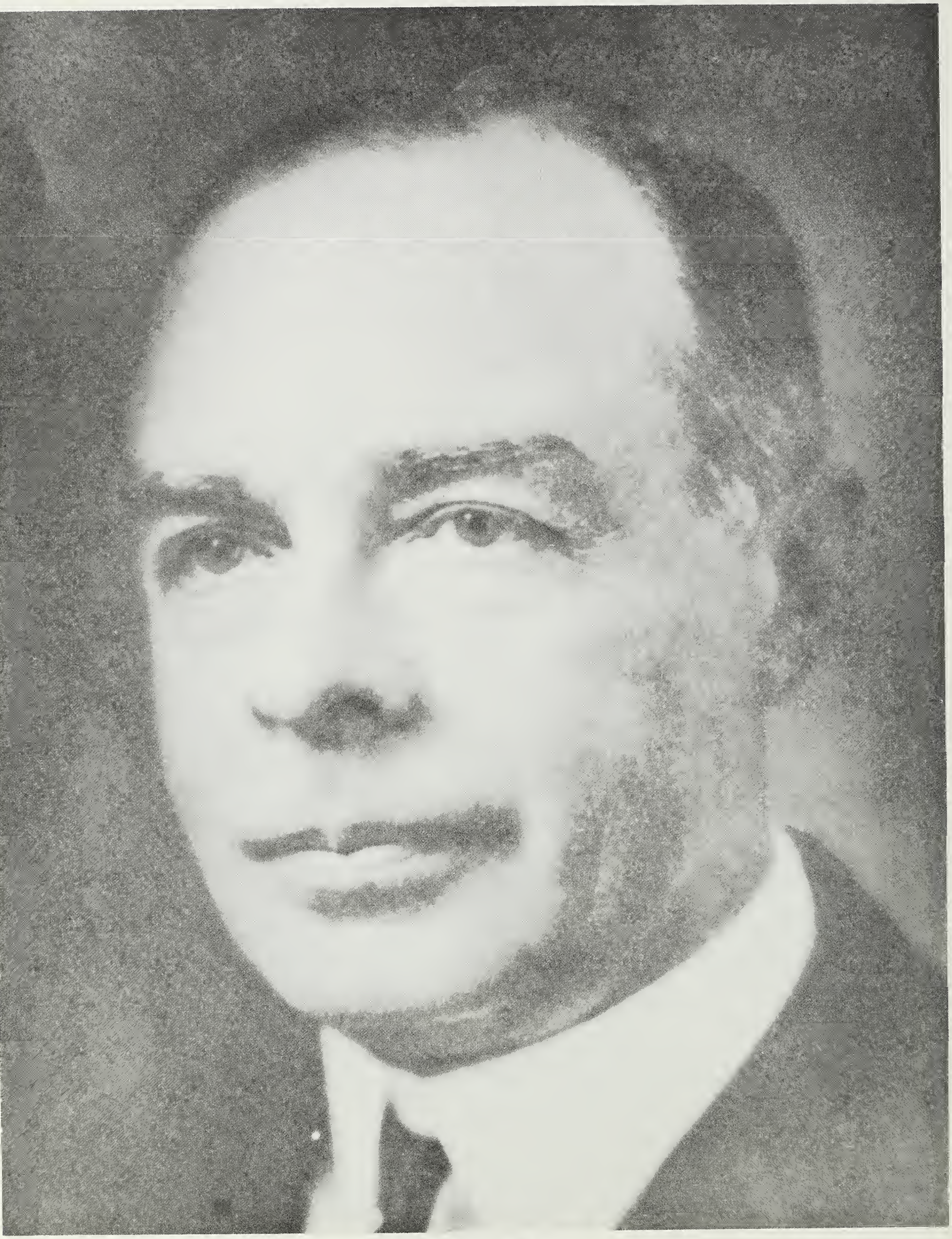
Mohler was born in Philadelphia May 2, 1875. He received his Doctor of Veterinary Medicine from Pennsylvania in 1896.

Soon after he became chief, the United States entered World War I; when he retired, the country was involved in World War II. And in the thirties the country experienced extreme drought and the change in policies in the New Deal. However, the Bureau profited by the increased funds available to it for research under his leadership and facilities were expanded apace.

Mohler had taken an active role in disease control and continued to emphasize this as the situation arose or the opportunity occurred. While he was chief of the Bureau, five diseases were eradicated—fowl plague, 1929; glanders, 1934; dourine, 1942; and cattle tick fever, 1943. He also sponsored the improvement of domestic animals by research in genetics and the application of scientific knowledge to breeding.

He was an active member and officer in a number of professional societies and was a prolific writer especially on diseases, their control, and eradication. In recognition of his leadership and contributions he received a number of awards.

At the time of his retirement, Claude R. Wickard paid tribute to his many accomplishments, saying that rarely did a departmental official contribute so much to the national welfare over so long a period. "Dr. Mohler," he said, "brought distinction to the Department of Agriculture as well as raising the Bureau of Animal Industry to a position of world pre-eminence in its field." He died February 29, 1952.



Arthur W. Miller
1943 - 1945

Arthur W. Miller was born in 1876 in Manchester, New Hampshire. He received the degree of Doctor of Veterinary Surgery from the Kansas City Veterinary College in 1901. From then until he transferred to Washington in 1917, he was involved in meat inspection and livestock disease eradication or control. He became chief of the Field Inspection Division in 1917 where he directed work with disease eradication or control, inspection of public stockyards for sanitation, and enforcement of the 28-Hour Law and quarantine regulations.

In January 1928, Miller was placed in charge of the newly established Packers and Stockyards Division and was appointed assistant chief of BAI in charge of regulatory activities. This Division was transferred to the Agricultural Marketing Service when it was established in the 1938/1939 departmental reorganization. Then Miller became chief of the Interstate Inspection Division, still continuing as assistant chief of the Bureau.

Upon the retirement of J. R. Mohler as chief of the Bureau in 1943, Arthur W. Miller succeeded him. He, in turn, retired 2 years later because of ill health. He died on September 1, 1955, after a long illness.

Bennett T. Simms
1945 - 1954

Bennett T. Simms was born at Emelle, Alabama, January 26, 1888. He graduated from Alabama Polytechnic Institute with the degree of Doctor of Veterinary Medicine in 1911. He spent a year in graduate study in pathology and bacteriology at the Rush Medical College in Chicago. Subsequently, he went to Oregon State Agricultural College where he taught, organized, and headed a Department of Veterinary Medicine.

In 1938 he entered the Federal service as the Director of USDA's Regional Animal Research Laboratory at Auburn, Alabama. There he directed extensive research on internal parasites of cattle and the development of methods for the use of phenothiazine for their control.

He was appointed chief of the Bureau of Animal Industry in late 1945 and continued in the position until the Bureau was abolished in 1954. Then he became chief of the Animal Disease Parasite Research Branch of the Agricultural Research Branch of the Agricultural Research Service (ARS). Two years later, he was appointed director of livestock research in ARS. He was active in veterinary and scientific organizations.

Soon after Simms became chief of the Bureau, plans were being prepared to launch an all-out eradication program against hog cholera. However, foot-and-mouth disease was spreading rapidly in Mexico. In the emergency, Simms led the U.S. work in eradicating the disease there, thereby preventing its introduction into our country. During his administration of the Bureau, plans were also developed for the Plum Island, NY, facility to research foot-and-mouth and other highly contagious diseases.

Dr. Simms retired from USDA in 1957. Thereupon, he served as a visiting professor of veterinary medicine at the University of Ankara, Turkey, and as an adviser to the Turkish Government. He also was on animal disease advisory committees of the United Nations Food and Agriculture Organization.

Upon his return to the United States in 1961, he became a consultant to USDA on research and disease control until his death on September 26, 1963.

Part I
HEALTHY LIVESTOCK — WHOLESOME MEAT: A SHORT HISTORY

By
Vivian Wiser
Historian, Economic Research Service, United States Department of Agriculture

BACKGROUND

From the early 1800's, agricultural societies and agricultural journals in the United States actively promoted the improvement of livestock as well as crop production and land use. Animals were imported and bred and were competitively shown at fairs, frequently called cattle shows. Movement of animals to these shows was restricted at times, however, because of concern about the spread of disease. Despite this concern, no provision was made, when the U.S. Department of Agriculture (USDA) was established in 1862, for any work on animal husbandry or veterinary medicine.

The first head of the Department, Isaac Newton, had operated a dairy farm and he was aware of some of the problems that livestock owners faced from diseases brought in by imported livestock. In 1865, he urged Congress to enact legislation providing for the quarantine of imported animals. But when the act was passed, jurisdiction was assigned to the Treasury Department instead of the new Department of Agriculture. Little preventive action was taken, imported animals continued to bring in disease, and livestock men complained increasingly. Newton recommended that imported stock be held in quarantine stations, but in vain.

In 1866 Jacob R. Dodge, USDA's statistician and editor, began collecting statistics on livestock and soon he added animal diseases. He published the information in the monthly and annual reports of the Department; in the absence of other regular information, these reports served as the channel for USDA dissemination of material on livestock.

Horace Capron, a former livestock breeder, became head of the Department in late 1867. Already cattle were bringing Texas fever, a debilitating and sometimes deadly disease, north into Illinois, Indiana, and Ohio, and then to the East. State laws were enacted to restrict movement of Texas livestock; States also directed their health departments or appointed commissions to resolve the disease issues.

After Capron's visit to the Springfield, IL, fair in the summer of 1868 he appointed John Gamgee, an English veterinarian, to study Texas fever. Gamgee had come over to demonstrate a method of meat preservation for the War Department—a demonstration that proved to be a fiasco. He was also cooperating with a commission, appointed by the Pork Producer's Association, that was studying Texas fever. Later that year Capron asked Gamgee to expand his study to include pleuropneumonia.

Meanwhile, State cattle commissioners met in Springfield in December 1868. They were divided as to who should undertake the needed studies of Texas fever, Congress, the War Department with its network of installations and experienced personnel, or the fledgling Department of Agriculture.

The commissioners supported Capron's request for $15,000 to continue Gamgee's work. Evidently Capron was anxious to expand work with livestock, for he recommended the establishment of a veterinary division in USDA.

Reports on Gamgee's findings on Texas fever, pleuropneumonia, and use of smutty corn along with reports prepared by the Surgeon General's Office for Gamgee, and a statistical and historical report of Jacob R. Dodge were published in 1870 under the title, *Report of the Commissioner of Agriculture on the Diseases of Cattle in the United States,* with 7500 copies printed for Congress. While some people were raising the possibility of a connection between the cattle ticks and Texas fever, Gamgee discounted such a suggestion.

Before long the *National Livestock Journal* was insisting that the Department of Agriculture perform its duty by studying diseases and developing methods of treatment. Dodge continued to include information on animal diseases in his USDA reports. But the contagious diseases continued to spread. The journal strongly condemned this situation,

especially since some diseases affected both animals and humans. These diseases attracted the attention of physicians as well as an increasing number of veterinarians and related practitioners. Papers were presented at meetings of the American Public Health Association and were published in its reports, including some by James Law, who had been associated with John Gamgee and had come to the United States to set up courses in veterinary science at Cornell University.

Swine breeders were also having problems with diseases that were reported to have killed as high as 75 percent of stock in some areas. In commenting on a convention in 1872 and the annual report of the Commissioner of Agriculture, the editor of *National Livestock Journal* urged the Department to make a thorough investigation of swine diseases, but none was undertaken at that time. Some groups attributed the spread of animal health problems to the treatment that livestock underwent as they were transported over the expanding railway system to distant markets. Moreover, the heavy losses and the inhumane conditions also built up a demand for changes. However, there was opposition to the Federal Government's intruding in what was considered private enterprise or, at most, a matter for the States to supervise. Nevertheless, on March 3, 1873, the 28-hour law was approved, requiring that livestock enroute for more than that period of time be fed and watered. United States marshals and circuit court judges were to enforce it. The Department of Agriculture had neither the authority nor the means to administer this act, which should have led to more humane treatment of animals and a better product for marketing at the end of the trip.

The medical profession also was involved in the discussion, stressing the interrelation of animal and human health. Moreover, they doubted the strength of the veterinary profession and its ability to handle the situation. They urged that a Sanitary Veterinary Bureau be established independent of either the Department of Agriculture or the National Board of Health. And once again James Law was involved, together with Lyman and E. H. Thayer.

States were strengthening their health departments and departments of agriculture. Annual reports as early as 1870 included studies of animal diseases. The first national meeting of the American Public Health Association (APHA) in 1873 included a paper on diseases of horses. Early volumes of APHA's *Reports and Papers* included papers by James Law, who would be making studies for the Federal Department of Agriculture, and Daniel E. Salmon, who was to become the first Chief of the Bureau of Animal Industry.

In 1876, the Missouri Board of Agriculture asked H.J. Detmers, a native of Germany who was vice president of the American Berkshire Association, to make a study of swine diseases. Soon USDA was urged to undertake a study because of prevalence of the diseases. Detmers was asked to head the USDA work and was assisted by a Thomas Healey. They visited infested farms, observed diseased hogs, inoculated some hogs, and killed some, which they examined for infestation. James Law was also working on the project.

The confused state of governmental activities, be they municipal, State, or Federal, were concomitant with the relatively new but rapidly expanding field of veterinary education. As early as 1877, some veterinarians began to look to the United States Department of Agriculture for support in bolstering the expanding field of veterinary education to meet the problems of livestock producers, handlers, and marketing agents. Subsequently D. E. Salmon promoted a college in the Nation's Capital for a brief time. And over the years BAI worked closely with the professional schools, organizations, and the Civil Service Commission to ensure an adequate supply of trained veterinarians.

Increased trade within the United States had intensified the hazards of spreading existent diseases. This was the era of increased total production of livestock, expanding markets, and European exports. Overseas, American-exported livestock competed with local animals that had many of the same diseases as well as other diseases not found in the United States. European countries imposed restrictions on U.S. livestock and meat trade. And the demands increased for the Treasury Department to impose quarantines against imported livestock; Duncan McEachran, a Canadian veterinarian, had urged the establishment of a system of quarantine stations in 1876.

The Treasury Department by the late 1870's took measures in view of the serious animal disease situation. For a 5-month period in 1879, no cattle were to be admitted from England, where there had been an outbreak of pleuropneumonia. Then customs inspectors were directed to hold cattle imported from Europe for 90 days at the importer's expense. But foot-and-mouth disease came in via Canada, although it did not become permanently established.

Britain and other European countries continued their restrictions of the late 1870's on importation of livestock and meat, evoking protests from the United States. Representatives of foreign governments in the United States were aware of findings of Federal, State, and other studies of diseases and of the agitation of the agricultural press for

a more aggressive program. They knew that a number of States along the east coast were centers for pleuroneumonia. To offset this threat, States took more positive action. But some looked to the "general government" as the ultimate hope in stamping out diseases at a lower cost than action by the separate States would entail.

Commissioner of Agriculture William Gates LeDuc, soon after his appointment in 1877, sent a circular letter to many veterinarians asking for assistance in getting an appropriation from Congress for a thorough investigation of animal diseases. An editorial in *American Veterinary Review* urged the Commissioner to establish a veterinary agency within the Department or an institute to train veterinarians to work with the diseases. A Senate resolution early in 1878 asked the Commissioner to furnish information on hog cholera and appropriated $10,000 for this purpose. Nine veterinarians or physicians were appointed to the Commission: James Law, H. J. Detmers, D. E. Salmon, R. F. Dyer, D. W. Vyles, C. M. Hines, Albert Dunlap, Albon Payne, and J. N. McNutt.

Unfortunately, each worked independently. A similar appropriation was made for each of the following 2 years. Divergent views came from the members of the commission. Their first report was a compilation of papers primarily on investigations of swine plague. The second report, by Detmers, Law, Charles Lyman, Salmon, and others, discussed further work on swine plague and investigations of tick fever and pleuropneumonia; it included correspondence on these subjects received by the Department. The third report also was primarily a discussion of swine diseases, pleuropneumonia, and shorter articles on other diseases, as well as correspondence and information on livestock conditions collected by J. R. Dodge, Departmental editor and statistician. So popular was the first report that Congress asked the Department to have 100,000 copies printed of the second report and 50,000 made of the third.

Another thread in the tangled web of animal disease activities was the National Board of Health, established by an Act of Congress in March 1879. Although its proponents had wanted jurisdiction over both human and animal health, it was assigned only the human health function, without any specifications on animal health. Nonetheless, it studied animal diseases, was supported by veterinarians as well as physicians, and attempted to extend its sphere at the expense of the Department of Agriculture. James Law was among the veterinarians supporting it. Frequently in discussions in the years ahead it sought to eclipse the incipient efforts of USDA to meet new challenges. In 1879, for example, the Department had directed Charles P. Lyman of Yale University to make a study of pleuropneumonia in New York State and then sent him to England to investigate the existence of pleuropneumonia among U.S. cattle shipped there. Lyman found some animals with pleuropneumonia, but the discussion ensued as to how it was contracted.

Still another thread in the web was the Treasury Cattle Commission, created by Congress in 1881 at the instigation of the Secretary of the Treasury. James Law again was on this commission along with E. F. Thayer of Massachusetts and J. H. Sanders of Illinois. They were assisted by other veterinarians who had been involved in previous surveys or worked in State departments of agriculture. Such a commission had been endorsed in 1879 by the *Livestock Journal,* which urged the appointment of a veterinarian, a livestock man, and a businessman to study the animal disease situation. The *Livestock Journal* feared that as transportation improved, diseased imported or eastern stock would decimate the western livestock industry.

The Secretary of the Treasury was well aware of the loss of foreign markets for livestock and meat products and had jurisdiction over the administration of customs regulations that could protect our livestock from imported diseased livestock. The 1882 report of the Treasury Cattle Commission included a historical survey of pleuropneumonia in Europe, Africa, Australia, New Zealand, and the Eastern United States. It discussed the threat to U.S. cattle from livestock which were intended for improved breeding, but which spread diseases. The impact of the diseases, the commission reported, had prompted some to urge widespread use of inoculation of animals, a policy it said was futile. Rather, the Federal Government should have authority to slaughter diseased stock, appraise their value, and indemnify owners. The 1883 report discussed problems involved in the importation and exportation of livestock. However, it did not recommend further action. A third and final report discussed cases of presumed foot-and-mouth disease that were investigated and determined not to be that disease but a condition generally caused by ergot in grain and hay fed to livestock. The Treasury Department imposed a 90-day quarantine on imported cattle and established quarantine stations in Portland, ME, Boston, MA, New York, and Baltimore, MD, but these quarantine stations soon proved inadequate.

At about the same time, 1883, the Department of Agriculture established a veterinary disease experiment station in the northeast section of the District of Columbia to study animal disease. Daniel E. Salmon had general jurisdiction over that and over the Veterinary Division established the same year. Thus, scattered and intermittent experimental work with animal diseases was consolidated and given permanent status within the Department and, as a new line of work, was under constant attack.

Benning Veterinary Experiment Station in the District of Columbia.

The year 1883 also saw the Secretary of State asking Commissioner Loring for two representatives of USDA to serve on a commission to study pork production and processing as well as European restrictions on U.S. imports. The commission was composed of representatives of the Chicago Board of Trade, the New York Chamber of Commerce, F. D. Curtis, of Charlton, NY, and George Bailey Loring and D. E. Salmon from USDA. The report was published the following year, defending U.S. pork, and stating that if trade required it, microscopic examinations could easily be instituted.

Loring, in addition to his work on the pork commission, called a meeting following the Illinois annual fat stock show in Chicago in November 1883 to discuss the disease situation, disease eradication, and needed legislation. Although he had hoped the meeting would be national in representation, few from the Eastern United States attended. However, a committee appointed there presented to the House Committee on Agriculture a suggested bill to establish a bureau of animal industry that paralleled the act of 1884.

Early in March 1884, near hysteria existed in Coffey County, KS, when supposed cases of foot-and-mouth disease were reported and publicized. The Governor appealed to Commissioner of Agriculture Loring and to the Army veterinary service. Loring first sent M. R. Trumbower and then Salmon to check on the outbreak. On his second trip Salmon met with James Law and other professors of agricultural colleges and the State veterinarians. They determined that the outbreak was not foot-and-mouth disease but ergotism.

ESTABLISHMENT OF THE BUREAU OF ANIMAL INDUSTRY

On May 29, 1884, Chester A. Arthur signed the act establishing the Bureau of Animal Industry (BAI) within the Department of Agriculture. It was to concentrate its efforts on controlling and eradicating pleuropneumonia and other diseases among domestic animals and preventing the exportation of diseased cattle. The law also provided for cooperation with States and territories in achieving these goals and prohibited interstate shipment of diseased animals under penalty of $5,000 fine or imprisonment. D. E. Salmon was appointed chief of the new Bureau and was assisted by Theobald Smith, a physician; William Rose, who had been in charge of the experiment station; and a staff, many of whom were paid on a per diem basis. The act establishing the Bureau included an appropriation of $150,000 but a limitation of 20 employees to tackle the momentous programs. It also directed the chief to issue rules and regulations to meet its mission. Series of these rules and regulations were published in the ensuing years to cover the increasingly varied functions of the Bureau and its successors. After 1936 they were published in the *Federal Register.*

Salmon started energetically on his pioneering work. Initially, primary emphasis was placed on pleuropneumonia, with inspection of premises where cattle were maintained, in cooperation with State and local authorities. An outbreak of the disease in Illinois and other adjacent areas west of the Appalachians required immediate attention. States and cities were hesitant to take aggressive action. But when the Department's authority to quarantine and destroy diseased livestock was established, its appropriations were increased to enable it to compensate owners for livestock

destroyed. The limitation on the number of employees was removed and the rate of eradication increased. Thus, on September 26, 1892, Secretary Jeremiah Rusk announced that the United States was free of pleuropneumonia—the first disease to be eradicated in the United States.

A 19th century BAI laboratory.

The various appropriation acts in the early years provided that part of the funds for BAI activities were to be allocated for research in the control of diseases of swine. By this time, Louis Pasteur had developed a vaccine for hog cholera that Salmon decided to try on pigs at the Bureau's experiment station. The ensuing unexpected outbreak of hog cholera precipitated the station into an active program using serums and vaccines. As time passed, various new materials were developed and used, but the task was so great and the disease so widespread that producers and the Department continued to attempt to control it rather than to eradicate it.

Texas fever was the third disease to which attention was directed, and about which there were countless opinions. Experiments were conducted at the Benning Station. Fred Kilborne, director of the station, Cooper Curtice, and Theobald Smith were involved in various capacities. In 1889, Smith announced that the cattle tick was the vector for the parasite that caused the fever. This was especially important because the idea that a vector could carry a disease was applied and used at that time in the control of yellow fever and malaria and subsequently to other diseases. U. G. Houck in his history of the Bureau of Animal Industry called this discovery one of the most important achievements in medical research.

This work on Texas fever highlighted one of the problems that plagued the Bureau. Controversy arose between the participants over findings and credit for publications or breakthroughs. In this instance, the discussions were continued by those involved for more than 40 years and then by other physicians and veterinarians even to the present day.

Early work in the Bureau in parasitology laid the groundwork for work in the ensuing years. In 1891, the *Index Catalog of Medical and Veterinary Zoology,* a guide to published material, and the National Parasite Collection were started and both continued until 1984, utilizing the latest techniques.

At another time when the work of the Bureau was under attack by outside scientists, Commissioner of Agriculture Norman J. Colman appointed a commission to study the work on swine diseases by the Bureau and by outside scientists. It reached no conclusion on the outside research but endorsed that of the Bureau. Criticism diminished as expanded work reached more people.

Tuberculosis was another disease included in the activities of the Bureau. Theobald Smith began using tuberculin, introduced by Robert Koch, for the detection of tuberculosis. The laboratories of the Bureau began manufacturing large quantities of tuberculin. Since Smith was a physician by training, interest in the effect of bovine tuberculosis on humans was a natural concomitant. Starting in 1900 imported cattle were to be given a tuberculin test. In 1905 the Bureau undertook the immunization of cattle against the disease. Then in 1906 a plan was inaugurated for the eradication of livestock tuberculosis in the District of Columbia—a plan that was soon expanded to include parts of Maryland and Virginia. The work was transferred the following year from the Pathological Division to the Quarantine Division as a regulatory activity. After a decade in which States and cities attempted to control or eradicate the disease, Congress on March 4, 1917, appropriated $75,000 for tuberculosis eradication. Two months later the Tuberculosis Eradication Division was established and the program was underway. The cost of eradication increased as $500,000 was appropriated the following year; in 1919, $1,500,000; in 1923, over $3,000,000; in 1944, $5,983,000; and in 1983, $3,705,608. Many field stations were established during this period to conduct cooperative work in the States.

Even in the early days, Bureau employees were involved in the identification and treatment of many diseases in addition to cholera, Texas fever, and tuberculosis—diseases including glanders and dourine in horses; contagious abortion (later referred to as Bang's disease or brucellosis) in cattle; foot rot and big head in sheep; diseases of poultry and other birds; and trichinosis and hookworm.

Another line of work was assigned to the Bureau, when on August 25, 1884, the quarantine stations of the Treasury Department were transferred to the Department of Agriculture. Three, and then four, stations were operated to quarantine cattle entering the United States near Baltimore, MD; New York; Boston, MA; and then Philadelphia, PA. The stations, along with customs offices along the Canadian and Mexican borders, served as guardians against foreign animal diseases. An act of Congress of August 30, 1890, extended the coverage of activities to sheep and other ruminants and swine and the importation of diseased animals, animals affected by any disease, or animals that had been exposed to any disease within 60 days of exportation. While these stations were essentially holding places for livestock coming into the country, they were from time to time used for research projects, i.e., the poultry and swine breeding projects of Halethorpe, MD, subsequently transferred to Bethesda, MD, and then to Beltsville, MD.

Meat Inspection to 1906

Livestock was an important factor in our 19th century trade. As shipments of our animals were restricted by foreign countries so also were shipments of animal products, especially pork. Especially strident were the charges from Europe of trichinosis infestation. Counter charges were made of varying standards for inspection of European domestic meat and U.S. meat. Producers and packers urged the government to undertake an inspection program that would enable them to compete in foreign trade.

The initial meat inspection act, approved in August 30, 1890, provided for the inspection of salted pork and bacon intended for export whenever the government of a foreign country should require it. The following year the act was amended to cover the inspection and certification of all live cattle for export and live cattle that were to be slaughtered and the meat exported. In addition, all cattle, sheep, and hogs whose meat was to be shipped across State or territory lines were to be inspected ante- and post-mortem at any slaughter house, canning factory, or processing plant. Farm slaughtered animals were exempt from inspection. On March 2, 1895, Congress amended the act authorizing the Secretary to provide for the disposal of condemned carcasses. Although there was some discussion of having the processors pay for the inspection service, no user fee was imposed. This legislation resulted in the addition of a new line of work and a rapid expansion of the staff of the Bureau across the country. Many young women were employed as assistant microscopists examining pork for trichinosis. Trichinosis examination was discontinued on June 30, 1906.

Another law which was supposed to affect interstate livestock trade was the 28-Hour Act passed in 1873, mentioned earlier. It provided that any livestock being transported by rail across interstate lines must be unloaded for feeding and watering at least once in every 28 hours. The law was intended as a humane and also as a trade improvement measure, but there was considerable discussion by 1905 that it was not enforced and that the feeding and watering facilities were inadequate in many areas. The law was reenacted in 1906 with provision for time extension to 36 hours when circumstances made the enforcement of the previous period impractical.

Organization

In the early days of the Bureau, frequently a single individual was involved in a line of work. Then, laboratories were

established and offices or divisions followed. In some cases, increases in activity reflected an expansion of the work authorized by new legislation; in other instances, they were to meet a special need or were the result of reorganizations.

By an order of Secretary Rusk in April 1891, the Bureau was organized in four divisions: Inspection, Animal Pathology, Field Investigations and Miscellaneous Work, and Quarantine. The Pathology Division was placed in charge of the animal and poultry disease work. Within it were the Zoology and Biochemical Laboratories. The Division had jurisdiction over diseases of livestock and poultry.

Supplementing these divisions as time passed were various offices, stations, and laboratories that subsequently became divisions. Thus, the Zoological Laboratory worked with Theobold Smith on tick fever and various aspects of parasitology. Later its chief, Charles W. Stiles, discovered the American hookworm to be widely prevalent in the Southern United States, a contribution that led to a worldwide eradication program under the International Health Board, the forerunner of the World Health Organization. The Laboratory became the Zoological Division on July 1, 1906.

The Biochemic Laboratory had a similar origin. Emil A. de Schweinetz was appointed January 1, 1890, and the Laboratory was established on April 1 of the same year. Initially, it was working primarily for other sections until 1896, when it was given divisional status. About this time, definite projects were set up to study dips and disinfectants for animal diseases, the systematic production of tuberculin and mallein, the relationship of bovine and human tuberculosis, and the production of a vaccine or antiserum for hog cholera.

In December 1897, at about the same time that W. A. Atwater was conducting his research in human nutrition, Henry P. Armsby of the Pennsylvania Experiment Station suggested to Secretary James Wilson that the Department should have similar work in animal nutrition. He and the Pennsylvania Experiment Station continued this research until 1920. In order to expand the work, George M. Rommel was appointed as expert in animal husbandry in 1901. In 1907, his unit became known as the Animal Husbandry Office and in 1910 became the Animal Husbandry Division. Early work with sheep was begun at the Bethesda Experiment Station and research with hogs and poultry was conducted at the Halethorpe, MD, Quarantine Station until its transfer to Bethesda. In 1910, a 475 acre tract was purchased for the use of the Dairy and the Animal Husbandry Divisions at Beltsville, MD.

The Inspection Division was assigned all field work of an executive nature, including the field investigation of contagious disease and the regulation of the movement of southern cattle. In 1912, the Division was reorganized into the Meat Inspection Division and the Field Inspection Division.

On February 1, 1890, R. G. Blaine was appointed as superintendent of quarantine stations. He became chief of the Quarantine Division when it was established in 1891 to supervise the importation, quarantine, and exportation of animals and their disinfection. In 1896, duties were added to the Division and the name was changed to Miscellaneous Division. On July 1, 1903, the Division was redesignated as the Quarantine Division. At that time it was primarily involved in inspection and quarantine of imported livestock, supervision of imported livestock by-products, inspection of exported livestock, and inspection of ocean vessels involved in this trade. In 1922, the Quarantine Division was merged into the Field Inspection Division.

The Bureau's work in tick eradication was conducted along several lines. First, experiments determined the tick to be the vector of Texas Fever. Various experiments were undertaken to protect cattle against the disease by dipping or otherwise eliminating the ticks, and to develop a method of vaccination or inoculation. Other efforts were made to eliminate the ticks in pastures. A system for the eradication of ticks was undertaken in 1906, but this was hindered in part by the attraction of veterinarians to the new meat inspection work authorized at about the same time. Early eradication work had been conducted by the Inspection Division, then in 1912 by the Field Inspection Division, and was expanded and appropriations greatly increased in 1917 with the resultant establishment of the Tick Eradication Division.

Early meat inspection work was conducted in the Inspection Division where a meat inspection laboratory was established. Following the passage of the more inclusive Meat Inspection Act in 1906, an assistant chief of the Division was appointed to supervise the expanded work and chemical investigations were conducted in six branch laboratories. In 1912, the meat inspection work was consolidated in the new Meat Inspection Division.

Emphasis in the early years was placed on inspection for the export market. However, by 1894, the Secretary urged the inspection also of meat and animals in the interstate trade. In his report he said such a beginning had been made.

Statistics show a steady increase in inspections after 1894.

The publication in 1906 of Upton Sinclair's *The Jungle* gave impetus to the divergent elements seeking change. The Meat Inspection Act was approved June 30, 1906. The new law was very specific on the inspection activities. It added provisions for the sanitary inspection of all establishments that slaughtered animals and prepared meat and meat products for interstate commerce, including canning, salting, packing, and rendering. The act also covered all meat products in interstate trade. Again farmers slaughtering their own stock were exempt from the act.

Early work with hog cholera consisted primarily of studies, laboratory investigations of the cause of the disease, and development of vaccines and serums for its treatment. After 1906, many of the hog cholera tests were carried on in a field station near Ames, IA. In 1916, the Office of Hog Cholera Control was created. Three years later, it became the Division of Hog Cholera Control. As the vaccines were developed, demand for them led to the establishment of many commercial firms. State controls of the firms proved ineffective, and on March 4, 1913, the President approved the Virus-Serum Toxin Act. The administration was assigned to the Biochemic Division. On February 17, 1917, the Office of Virus-Serum Control was set up, to become, on July 1 of that year, the Division of Virus-Serum Control.

The establishment of the Dairy Division in 1895 was a reflection of the growing importance of the dairy industry. As the industry expanded, problems had increased. The United States was losing its export markets because of the uncertain quality of some of our dairy products. A number of articles on dairying, butter, milk, and cheese had been published by the Department. In his report for 1895, Salmon had announced that he was establishing a dairy division as of July 1, 1895. At first, it would be concerned with collecting and disseminating information on the existent dairying situation. He deplored the Department's neglect of this facet of agriculture and looked forward to the time when research facilities would be available. In the ensuing years much attention was given to promoting the dairy industry at home and expanding markets abroad. In 1902, both laboratory research and inspection of renovated butter began, as directed by Congress. Three years later, dairy extension work was started in the South at about the same time that other extension work was beginning under the aegis of the U.S. Department of Agriculture. In 1910, expanded research facilities became available at the Beltsville, MD, farm, purchased in that year. About 185 acres were assigned to the Division for its use, but land had to be cleared and barns and laboratories built. Other farms were subsequently established at Jeanerette, LA; Ardmore, SD; Huntley, MT; and Woodward, OK.

Agitation for a separate bureau of dairy industry began as early as 1907 and reemerged in 1912-13. Then with the support of Representative Gilbert Haugen and Senator Charles McNary, the Bureau of Dairy Industry became a reality: on July 1, 1924, the Dairy Division became the Bureau of Dairying under the direction of Carl Larson. Two years later it was redesignated as the Bureau of Dairy Industry. Initially organized by projects, it was, on May 1, 1929, reorganized into Divisions: Dairy Cattle Breeding, Feeding and Management Investigations; Market Milk Investigations; Dairy Herd Improvement Investigations; and Dairy Manufacturing Investigations and Introduction. On October 1, 1935, the Division of Dairy Manufacturing Investigations was abolished and its functions were transferred to the Division of Dairy Research Laboratories. A year later the establishment of the Division of Physiology and Nutrition was approved.

When, on February 23, 1942, the general direction of scientific research was placed in the Agricultural Research Administration, the Bureau of Dairy Industry was placed in it. Later during World War II the Division of Market Milk Investigations, on February 21, 1944, was absorbed in the Division of Dairy Research Laboratories. The number of employees in Bureau of Dairy Industry remained fairly steady with 273 in 1940, 290 in 1946, and 304 in 1950.

As part of Secretary Benson's reorganization of the Department of Agriculture in 1953, the scientific Bureaus lost their separate identities. At that time the Bureau of Dairy Industry was composed of the following Divisions: Dairy Herd Improvement Investigations; Dairy Cattle Breeding, Feeding, and Management; Nutrition and Physiology; and Dairy Products Research Laboratories.

Cooperation with the Defense Agencies

The activities of the Bureau of Animal Industry were rapidly expanding to meet the needs of the Nation. Following the Spanish-American War and the criticism of the spoiled meat that had been fed to the United States Army, resulting in some deaths, a veterinarian was transferred from BAI to the War Department. There he was to be a meat inspector at large for the Subsistence Department of the U.S. Army.

The Bureau continued to cooperate with the Army and the Navy, inspecting their food. Subsequently it worked with

the War Department in its military horse breeding program.

The Bureau's activities were expanding as World War I threatened in Europe. The Virus-Serum Toxin Act had been passed in 1913; Congress, seeking to increase production, authorized funds for more work with disease eradication and control. For example, $75,000 was provided in 1917 for work with tuberculosis, and funds were provided under the Food Production Act for increasing the yield of animal products for food and clothing. The Bureau held meetings and prepared articles, bulletins, and pamphlets to increase healthy herds and flocks.

At the same time that the scope of the work became greater, some 325 employees were "called up" for military service. Others left for more remunerative positions. Bureau people were at the same time inspecting meat for the Army, Navy, and Marine Corps. In 1917, the War Department asked that BAI increase its assistance in meat inspection for the Army and 64 inspectors were detailed to various installations. During its period of cooperation, BAI inspectors checked 376,298,310 pounds of meat, rejecting 7,761,633 pounds. It also assisted the Naval Academy with its dairy farm and inspected butter for the Navy Department. Moreover, the Bureau furnished mallein to the Army for treatment of dourine in horses.

During the war, France and England purchased large numbers of horses in the United States. It has been estimated that over a million horses were exported for "war needs."

Although there were motorized units in World War I, a squadron of cavalry was sent to Europe. In addition, many horses and mules were sent. Horses sent over were subject to diseases of the conflict areas. And by the end of the war, dourine was quite widespread, especially in France. When the animals were brought back in 1919, therefore, BAI inpectors were at ports of entry to check them for diseases. Samples of blood serum or smears were examined, but few cases of diseases were found.

The Post World War I Years

The ravages of war in Europe were reflected in an increased postwar demand for American cattle primarily to upgrade European livestock. At times the pressure was great enough that governments were anxious to accept the shipment of animals without the usual certification of health.

The year 1919 also saw the greater involvement of the Bureau in drought relief work. There had been droughts in Texas in 1917 and 1918, necessitating assistance to livestock producers in relocating their stock to productive pastures. Some were moved to the Southeast and provided a stimulus to the industry there. But 1919 was the third year of drought in the Northwestern States. Stockmen appealed through their Congressmen for assistance from USDA. The Secretary appointed a committee composed of representatives from the Bureau of Animal Industry, the States Relations (extension) Service, and the Bureau of Markets. Some emergency food supplies were shipped into the affected area. Offices were established to assist producers in marketing livestock and in locating pastures in nearby States. By this time, pastures in Texas and New Mexico had recovered and stockmen there were anxious to replenish their herds. This need provided an outlet for Montana and other stricken States to the North, with 300,000 cattle and between 500,000 and 600,000 sheep moving out of the Northwestern drought area.

Programs begun or expanded during the wartime period had generally been so successful that many became part of the continuing program of the Department. Tuberculin and mallein that had been manufactured for the War Department was now available for an expanded program in tuberculosis control. Similarly, the attacks on hog cholera and other diseases were continued. And as the threat of foot-and-mouth disease seemed a constant threat, the Bureau by 1929 placed in convenient points throughout the country equipment and supplies to be used if the disease should break out; and personnel were trained to combat it.

Animal and poultry husbandry was an important feature of BAI's work in the 1920's. Great emphasis was placed on improved breeding through better sires and developing and expanding new breeds, i.e., Columbia sheep. Experiments were conducted at various locations.

Remembering the drought during and after the war, the Bureau during the drought of 1930 directed its attention to advance measures for reducing losses. It prepared a bulletin on handling livestock during drought. But the continued drought in the 1930's required more stringent measures.

The Bureau and the New Deal

The 1930's were years of change for the Bureau of Animal Industry as the Department took on new action programs to meet the agricultural emergency. In August 1933, J. R. Mohler, chief of the Bureau, viewed the place of his agency under the "controlled agriculture." Its research and regulatory activities had provided technical information for planning effective agricultural adjustment, a function continued in the ensuing years. As the Department faced the impact of the drought on the nation's cattle, Bureau personnel were involved in inspecting animals moved from drought areas to adequate pastures.

When the Agricultural Adjustment Administration (AAA) proceeded with the Emergency Hog Marketing Program in 1933-34, inspectors from BAI determined the eligibility of the pigs and sows for purchase. They also assisted in the purchases by packers, supervised the processing, and certified the purchases of each packer so he would be reimbursed for animals bought and processed into edible food.

On May 21, 1934, Chester Davis, Administrator of the AAA, appointed E. W. Sheets, who had been chief of the Animal Husbandry Division of BAI, as Federal Director of Drought Relief. Sheets served only 3 months in this capacity. J. R. Mohler, chief of the Bureau and O. E. Reed, chief of the Bureau of Dairy Industry, also served on the committee to determine action to be taken. The Bureau was actively involved in the drought cattle purchase program in which personnel inspected livestock brought for sale, condemning those unfit for human consumption - almost 18 percent of those purchased. When a location had too many cattle to handle, the BAI inspectors were responsible for shipping the surplus elsewhere as instructed by the Federal Emergency Relief Administration.

Emergency programs and emergency funds also provided an opportunity for weeding out inferior livestock and for controlling or eradicating disease. And this all involved the employment of up to 3,800 BAI temporary employees inspecting and slaughtering animals reacting to tuberculosis, Bang's disease, etc.

World War II, the national defense program, and increased foreign food demands necessitated increased food production, highlighting the problems of livestock production and meat processing. This meant intensified research on meat, wool, eggs, and other critical commodities and technical assistance to war agencies. Emphasis was placed on improved feeding and management, and management of livestock to increase production. Work on disease eradication and control was continued, but that with brucellosis was handicapped by a shortage of veterinarians.

Personnel in BAI.

The number of people employed in the Bureau of Animal Industry initially was limited by law to 20. It lost some employees when the Bureau of Dairying was established in 1924. Three years later the overall figure increased to 4,171 when the administration of the Packers and Stockyards Act was transferred to BAI. Increased funds also provided for more work at experimental farms, including that at Beltsville, MD. The number of permanent full-time employees remained fairly constant during the depression years of the 1930's. However, many were involved in emergency programs or expanded disease control or eradication under emergency funds. In 1934, 684 employees were assigned to emergency work on cattle reduction and disease eradication. During the 1930's there were also many temporary employees in the Bureau: 1935, 380; 1936, 2,550; 1937, 2,845; and 1938, 2,553. During World War II many of the regulatory activities of the Bureau and employees were transferred to the Food Distribution Administration (Dec. 1942), resulting roughly in a two-thirds reduction. As postwar reorganization restored many functions, BAI expanded again to more than its prewar size and in 1949 had 7,873 employees. The following year, however, it was down to 6,811.

Legislation for Research

Much of the legislation supporting agricultural research has been enacted in appropriation acts or for specific lines of work. Frequently in the realm of animal science there has been provision for both regulatory and research activities. As emergencies arose, special funds were available during World War I, the New Deal, and World War II.

However, there have been general laws cutting across disciplines to promote the improvement of agricultural production and marketing.

The Bankhead-Jones Act, approved by President Roosevelt on June 29, 1935, represented such a step forward in funding research in USDA and the State experiment stations. Among the regional laboratories involved in animal research

that were established under this act in 1937 were the sheep breeding laboratory at Dubois, ID, the swine breeding laboratory at Ames, IA, and a laboratory at Auburn, AL, for studying diseases and parasites of domestic animals. The following year, a poultry laboratory was set up at East Lansing, MI. The work of these laboratories was complemented by the provisions of the Agricultural Act of 1938 providing for regional laboratories studying the utilization of animal and poultry products.

USDA's authority over animal diseases as provided in the 1884 act establishing the Bureau of Animal Industry was expanded in September 21, 1944, when that act was amended. Under the new legislation, the Secretary of Agriculture was authorized to cooperate with States and their political subdivisions, farmers' associations, and similar organizations and individuals in the control and eradication of animal diseases.

The Research and Marketing Act signed by President Truman on August 14, 1946, provided additional funds for research by the Bureau of Animal Industry. Investigations were made of the cause, prevention, and control of X - disease or hyperkeratosis of cattle, methods for controlling internal parasites of cattle in the South, and the continuous growth in beef cattle at various feeding levels as compared with restricted and subsequent accelerated feeding. Studies were conducted on the life history, distribution, habits, and control of the more important species of deer flies and horse flies. Other investigators were involved in poultry breeding as well as with breeding dairy cattle and crossing red Sindhi cattle with domestic cattle to develop heat tolerance. Much attention was also given to the marketing of animal, dairy, and meat products.

Parasitology Research

Work in parasitology continued apace with regulatory and veterinary medicine and animal husbandry research. The work in one discipline at times contributed to other activities. Through the years, scientists have identified many economically important parasites of domestic animals and birds, thereby developing a better understanding of parasite induced pathology and of control measures. In 1938 and 1939, research of Paul Harwood led to the discovery of the value of phenothiazine, a synthetic organic chemical, for removal of many kinds of internal parasites of livestock and poultry.

In 1960, Frank Douvres developed methods for growing livestock parasites in artificial culture systems, outside the body of the host. Later he made significant progress toward "deparasitization" of parasites.

Following up on earlier research that developed the complement-fixation test for the diagnosis of anaplasmosis, Gene Amerault and T. O. Roby in 1968 devised a rapid card agglutination test for the serological diagnosis of bovine anaplasmosis on the farm as well as in the laboratory.

David Doran scored a major advance the following year toward the development of a protective vaccine against avian coccidiosis.

Another important project resulted in the identification of female trichostronglids that made it possible to characterize nematodes of vertebrates.

Research on parasitology also has found that parasites develop resistance to drugs and thus methods for their control must be constantly changed.

Reorganization

The scope of the work had increased in the first 40 years of the history of the Bureau. Whereas in 1891 there were 4 divisions, by 1924 there were 12. Some of the new or expanded activities were authorized by appropriation acts, while others were by specific legislation.

Similarly when the bureau was first established, the chief reported directly to the head of the Department. When the Department was elevated to Cabinet status in 1889, however, Salmon found that there was then an Assistant Secretary to coordinate scientific work. A director of scientific work, who would not be subject to change when the administrations changed, was appointed in 1897; 6 months later the position was abolished and Secretary James Wilson was in charge. Soon after David Houston became Secretary of Agriculture in 1913, Beverly T. Galloway, who had been

chief of the Bureau of Plant Industry and was Assistant Secretary, drew up a proposed general reorganization of the Department. Under this plan, the agency would have been reorganized into functional services; i.e., weather, forestry, research, regulatory, States relations, etc. The bureaus would have been abolished. With the strong opposition of the bureau chiefs, the idea was essentially dropped, to resurface about 40 years later and be implemented.

The idea of a coordinator for research surfaced again in 1921, and a Director of Scientific Work was appointed to advise the Secretary and bureau chiefs and to coordinate scientific work. The position was abolished upon the retirement of Albert F. Woods in 1934. Two years later the chief of the Office of Experiment Stations was named as Director of Research, but he had little impact on BAI's activities.

Changes in functions of BAI were reflected by internal organizational adjustments. On June 1, 1934, the Tick Eradication Division was combined with the Division of Hog Cholera Control to form the Division of Tick Eradication and Special Diseases. Other divisional changes are discussed in the chronology at the end of this section. However, the transfer of the enforcement of the Packers and Stockyards Act from BAI to the new Agricultural Marketing Service in 1938 was part of Department-wide changes.

In December 1941, as the Department readied itself for an emergency situation, an agricultural research administrator was appointed as part of a grouping of Departmental agencies. On February 23, 1942, the Agricultural Research Administration was established, consisting of the scientific bureaus, which retained their identity at this time. Following the realignment of USDA activities on December 2, 1942, to meet the challenges of a nation at war, enforcement of the meat inspection law, the 28-hour law, and related activities were transferred to the Food Distribution Administration. These were transferred back to BAI on October 1, 1946. Seven years later, in 1953, a new administration drew on the recommendations of the Hoover Commission and inaugurated sweeping organizational changes in USDA. The scientific bureaus, including BAI and the Bureau of Dairy Industry, were abolished and their functions were transferred to the newly established Agricultural Research Service (ARS). Under the new Service, activities of the former bureaus were assigned essentially to the Deputy Administrators for Regulatory Work and for Research. These had, respectively, Directors of Livestock Regulatory Programs and Livestock Research. For nearly two decades, with some redesignations, the organization continued.

A change in the top level organization took place in 1963 when Nyle C. Brady was appointed as Director of Science and Education to provide general direction of the work of the Agricultural Research Service (ARS), the Cooperative State Research Service (CSRS), the Extension Service (ES), and the National Agricultural Library (NAL). A decade later the position was allowed to lapse and its functions were assigned to the new Assistant Secretary for Conservation, Research and Education. Meanwhile, in 1972, the Agricultural Research Service had been reorganized, decentralizing control through the establishment of regional and area offices, with Deputy Administrators in charge of each region. About 250 employees were sent from Washington, DC, to the States.

A National Programs Staff was established to serve in a policy position for the Administrator of the ARS, with a staff for livestock and veterinary services headed by an assistant administrator. Much of the staff in the Washington, DC, area, including the Beltsville, MD, research center, was essentially assigned to the Northeastern region. At top level, 1978 saw another grouping when the Science and Education Administration was established providing a super agency over ARS, CSRS, ES, and NAL. Three years later they resumed their separate identities.

On October 26, 1971, the Animal and Plant Health Service was established to administer all regulatory functions of the Agricultural Research Service, a recommendation of the General Accounting Office. The new agency's functions were expanded when the meat and poultry inspection work was transferred from the Consumer and Marketing Service and on April 2, 1972, the name was changed to Animal and Plant Health Inspection Service (APHIS).

On March 14, 1977, the Food Safety and Quality Service was established and was assigned, from APHIS, responsibilty for the inspection of meat and poultry products and, from the Agricultural Marketing Service (AMS), meat and poultry grading and standardization. On June 17, 1981, the latter functions were transferred back to AMS and the agency was redesignated as the Food Safety and Inspection Service (FSIS).

In the years that have followed, top level changes have taken place, and changes have been made in the numbers of employees involved in administration vs. research. At times these changes have had a disquieting impact on scientists in ARS. However, the establishment of the Science and Education Administration in 1978 and its later abolition

in 1981 were considered as of little concern to those viewing it as merely another layer at the top. Again, in 1983, shifts of personnel were made in ARS with the avowed purpose of placing more emphasis on research rather than administration.

Relations with Food and Drug Administration

The Food and Drugs Act was passed in 1906 in response to the persuasive activities of Harvey W. Wiley. Wiley was in charge of the USDA work in chemistry from 1883 to 1912. The Food and Drugs Act was administered by his Bureau of Chemistry from 1906 until 1940 when this responsibility was transferred to the Federal Security Agency. The Food and Drug Administration (FDA) is now in the Department of Health and Human Resources.

The BAI and its successor agencies have continuously shared responsibility for consumer safety of meat, poultry, milk, and eggs and all manufactured food products in which they are used. FDA establishes the conditions of permitted use of veterinary drugs, including their feed use, and of curing and preservative substances. USDA participates in research on efficacy and safe use of drugs in animal production. FSIS analyzes samples of food products of animal origin for residues and reports violative residues to FDA. FDA and USDA agencies cooperate in identification and elimination of sources and causes of hazardous violative residues.

Participation of USDA agencies has led to development and application of sensitive, reliable methods of chemical analysis. These USDA contributions have led to FDA decisions to withdraw permission for use of diethylstilbestrol for beef cattle, and to reduce amounts of nitrite permitted for use in curing meats and other products because nitrite is a potential contributor to formation of carcinogenous nitrosamines in such products. Research and review continue to evaluate the alleged compromise of antibiotics' therapeutic properties by their use in animal feeds to promote growth.

Meat Inspection, 1906-1984

The administration of the 1906 meat inspection act was assigned to the Inspection Division of the Bureau of Animal Industry. The early days were full of problems and criticism, but the work went on. By 1912, the work had grown so that a separate Meat Inspection Division was established.

The following year, a provision of the tariff act provided for the inspection of imported meat. The activities of the Division were further expanded by the passage, in 1919, of the act for the inspection of horse meat and meat food products thereof. Then, too, the Division was inspecting meat for the Army and the Marine Corps during and after World War I.

During the 1930's the Meat Inspection Division inspected meat processed under some of the emergency programs.

As the Department reorganized to meet the challenges of World War II, the Meat Inspection Division was transferred on December 5, 1942, to the Food Distribution Administration. Less than a year later it became part of the Office of Distribution. In 1945, meat inspection was transferred to the new Production and Marketing Administration. The following year, it was transferred back to the Bureau of Animal Industry.

Although the question of charging industry for the meat inspection service had been discussed from time to time, it was finally enacted into law in 1947, but the next year it was repealed. In the early 1980's, the question was widely discussed again.

When the Bureau of Animal Industry was abolished in 1953, meat inspection activities were transferred to the Agricultural Research Service where it became the Meat Inspection Branch under the Deputy Administrator for Regulatory Programs. The enforcement of the Humane Slaughter Act of 1958 became an added duty of the Meat Inspection Branch.

Over the years both the States and the Federal government had had separate meat inspection systems with programs of varying standards from State to State and duplication of efforts between the State and Federal system. In 1962, the Talmadge-Aiken Act was passed to remedy this conflict. The Secretary of Agriculture was authorized to enter into cooperative agreements with State departments of agriculture and agencies in administration and enforcement of Federal laws. However, few States took advantage of its provisions.

When the Consumer and Marketing Service was formally established on February 8, 1965, the meat and poultry inspection services were brought together under a central administration. However, three separate divisions handled the

meat inspection and a separate structure existed for field operations.

The meat inspection system has become increasingly complicated as the marketing system changed. To remedy some of the problems and also to ensure uniformity in the treatment of goods shipped in intra- and inter-state and foreign commerce, the Wholesome Meat Act was passed in 1967. In effect, the new act consolidated in one statute the 1906 Act, the Horse Meat Act, and the import inspection provisions of the 1913 and 1930 Tariff Acts. States were to conduct an adequate inspection of the country's meat. The act provided for the Federal government's paying 50 percent of the cost of State inspection under cooperative agreements.

Following the enactment of the Wholesome Poultry Act in 1968, the two inspection programs became more parallel and were merged organizationally in the Consumer and Marketing Service. The programs have been under constant study by USDA, congressional committees, and the General Accounting Office. Research on improving methods or utilizing new techniques have been constantly pursued, and, of course, organizational changes have continued. When Animal and Plant Health Inspection Service was established in 1972, meat and poultry inspection became a part of it instead of becoming a separate agency, as recommended by a study by the General Accounting Office. An associate administrator was placed in charge of this segment. Five years later, following an extensive departmental study, the Food Safety and Quality Service was established with responsibility for meat and poultry inspection, humane slaughter, egg products inspection, and grades and standards for meat and poultry. In June 1981, grades and standards work were transferred back to the Agricultural Marketing Service. Meat and poultry inspection became the primary function of the reorganized Food Safety and Inspection Service.

The meat inspector of 1906 faced his challenges, but duties of the current corps of inspectors have changed as much as the worlds in which they lived. And the Department's administration of the program is under the scrutiny of many opposing groups. Thus, the program seems in a constant ferment to provide the American public with the best available food at the lowest cost.

The other side of the program that has proven equally valuable has been the research activities. These have enabled the Department to set standards, develop efficient procedures, and enable the inspectors to utilize the latest techniques in an increasingly complex market place.

Poultry Inspection

The poultry inspection program has had a shorter period of growth than the meat inspection program, due, no doubt, to its later development as an industry. Mary Pennington and others from USDA's Bureau of Chemistry, which for two decades enforced the Food and Drugs Act, were conducting early studies of poultry slaughter and storage. Then the Office of Markets and the Bureau of Agricultural Economics made other studies. During the 1920's following an outbreak of fowl plague in New York, a live poultry examination program was instituted by the New York Live Poultry Commission. In 1926, this program was taken over by USDA and 2 years later was extended to include dressed poultry and edible products for condition and wholesomeness. Other cities followed suit, requiring USDA inspection for incoming poultry products. This program was called voluntary since no legislation required the inspection.The mark of inspection proved a valuable asset to the poultry industry and work expanded. The Agricultural Marketing Act of 1946 gave further impetus. Congress was alert to the public interest in wholesomeness of poultry by the midfifties. Hearings with consumer, industry, and government groups were held. On August 26, 1957, the Poultry Inspection Act was approved providing for compulsory inspection of poultry sold in interstate or foreign commerce. In 1968, much-needed revisions in the Poultry Products Inspection Act became a reality. This was supplemented December 29, 1970, by the enactment of the Egg Products Inspection Act.

The Packers and Stockyards Act

The initial meat inspection act had provided for the inspection of pork and bacon being exported. Then inspection was extended to other meat and livestock for export. Some inspection of interstate commerce was made but BAI did not have the resources to expand the coverage to all such trade. Following the 1906 passage of the meat inspection act, not only were all interstate shipments to be covered but also sanitary inspections were to be made of plants.

However, no provision was made to cover business practices in the industry. There surfaced criticism of practices of the big packers and stockyards. In 1916, President Wilson asked the Federal Trade Commission to make an investigation of the industry. During World War I regulation of activities of such plants was under the jurisdiction of the United

States Food Administration.

The report of the Federal Trade Commission came out in six parts beginning in July 1918. It revealed monopolistic practices of the major packers as well as many unfair and deceptive trade practices preventing free, open, and competitive marketing of livestock. Congressional hearings were held at about the same time on the government control of the meat industry in which the Chamber of Commerce and the meat packers objected to the manner in which the study had been made. Nonetheless, there were demands that the industry be regulated. The Justice Department instituted antitrust proceedings against the Big Five that ended in a consent decree in 1920, in which they agreed to dispose of many of their interests and refrain from dealing in retail activities and many non-meat foods.

The Packers and Stockyards Act was approved August 15, 1920, to regulate practices of meat packers engaged in interstate commerce and the marketing of livestock through public stockyards. In 1935, the act was amended to include the poultry industry. In 1938, it was amended to cover auction markets. The Packers and Stockyards was broadened in 1958 to give the Secretary of Agricuture jurisdiction over all interstate livestock marketing including country buying of livestock and auction markets regardless of size. In 1976, Congress amended the act to give greater protection to those selling livestock to packers and strengthened other provisions of the act.

The Packers and Stockyards Administration existed as a separate agency until July 1, 1927, when its functions were transferred to the Bureau of Animal Industry. In the reorganization of 1938-39, it became a part of the new Agricultural Marketing Service. In the subsequent organizational changes during World War II, it was successively in the Agricultural Marketing Administration, the Food Distribution Administration, and Office of Marketing Services. When the Production and Marketing Administration (PMA) was organized in 1945, the administration of the Act became part of that agency. In 1953, when PMA was abolished as part of the general Department reorganization, the function was assigned to the new Agricultural Marketing Service. In 1965, AMS was redesignated as the Consumer and Marketing Service. Later that year, and for a decade to follow, the function was administered by an independent Packers and Stockyards Administration. Then the function was transferred back to AMS with a deputy administrator in charge. Four years later, on June 17, 1981, the Packers and Stockyards Administration became a separate agency again, reporting to the Assistant Secretary for Marketing and Inspection Services.

International Activities

As the Department had earlier sent its representatives to Europe to determine whether our exported cattle and meat were as diseased and as unfit for human consumption as other countries claimed, Salmon and three other Bureau employees went to Europe in 1890 to check livestock being exported to the United States or livestock exported to Europe. They and their successors worked alongside their British counterparts. From time to time the Bureau also sent representatives abroad to investigate or inspect conditions in countries that wanted to export livestock to the United States. Of these representatives, Dr. Henry Burke was lost in 1915 with all his records when the ship *Marowijue* sank during a West Indian hurricane, and Dr. Henry Hart died in 1916 in a hotel fire set by Mexican bandits under the leadership of Francisco Villa. These are only two of those who died in line of duty.

Bureau personnel continued to check on disease conditions abroad, were involved in assuring our overseas market of the quality of our shipments, and conducted inspection of imported meat and livestock at United States ports of entry and at some overseas locations. An International Programs Division was established in the Agricultural Research Service.

Recently overseas research stations have been established—the Asian Parasite Research Laboratory at Seoul, Korea, the European Parasite Research Laboratory at Sevres, France, and the Animal Disease Research Laboratory at Nairobi, Kenya.

The Department has cooperated with other nations in disease control or eradication efforts. Foremost among these was the work in the late 1940's and early 1950's in cooperation with Mexico, under the leadership of Bennett J. Simms, to prevent foot-and-mouth disease from spreading from Mexico to the United States. The Department has cooperated with Central American countries and other Western hemispheric countries. Most recently it cooperated in the program to eradicate African swine fever in Haiti and Santo Domingo. The project was undertaken by the Interagency for Cooperation in Agriculture with the cooperation of the United States, Canada, and Mexico.

The Animal and Plant Health Inspection Service has also been cooperating with Mexico in a campaign to eradicate

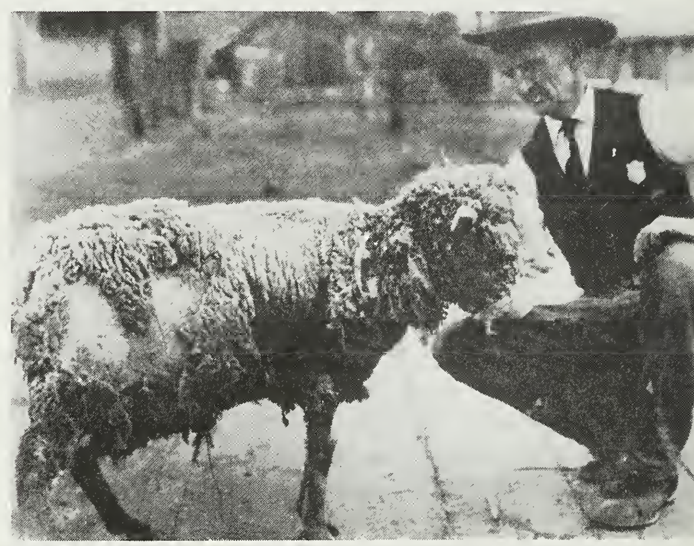
screwworms in Mexico. An agreement was signed on August 28, 1972, to cooperate in an effort to rid the area of screwworms down to the Isthmus of Tehuantepec. A sterile fly factory was constructed near Tuxtla Gutierrez, Chiapas, in southern Mexico. Sterile fly production was begun in September 1976; in 1981 a similar facility at Mission, TX, was closed and all production was shifted to Tuxtla.

The plan was to eradicate the disease by stages, dividing the country into five zones from north to south. Sterile flies were taken to centers throughout Northern Mexico and were dispersed in areas where wild flies existed. When control was effected in one zone, efforts were moved to the next zone to the south. In early 1984, Mexico was free of screwworms north of Mexico City. The fly factory at Tuxtla Gutierrez, Chiapas, was producing 500 million sterile flies a week. It was expected that the eradication would be completed to the 92nd Meridian by January 1, 1985.

Disease Eradication

Through the efforts of the Bureau of Animal Industry and its successors, the Agricultural Research Service and the Animal and Plant Health Inspection Service, 12 major animal diseases have been eradicated in the United States: bovine pleuropneumonia, 1892; fowl plague, 1929; foot-and-mouth, 1929; glanders, 1934; dourine, 1942; cattle tick fever, 1943; vesicular exanthema, 1959; screwworm (Southeast, 1959), (Southwest, 1966); Venezuelan equine encephalomyelitis, 1971; sheep scabies, 1973; exotic Newcastle disease, 1974; and hog cholera in 1978—17 years after Congress provided for an expanded program. And, of course, from time to time other diseases have been eradicated before they spread to alarming proportions. Nonetheless, they threaten our livestock. Contagious equine metritis is such an example.

In 1948 cattle with foot-and-mouth disease were destroyed as a control measure to prevent the spread from Mexico into the United States.



The effects of sheep scabies is obvious in this photo taken around 1914.

The approaches and methods have varied as have the number of people involved and have meant close cooperation between Federal and State authorities with producers.

Avian flu currently has brought into play the resources of APHIS and has shown the speed with which the agency can react when faced with a crisis. At the same time, avian flu has highlighted the problems and frustrations of the Department of Agriculture, the States, and producers as they cooperate to eradicate this threat to the industry.

The road between the early work of the Bureau of Animal Industry with pleuropneumonia and hog cholera and the Animal and Plant Health Inspection Service with avian influenza has had many turnings. It illustrates the changes that have taken place in the work in disease control and eradication. Another early function, meat inspection, has grown from inspection of export meat by the Bureau of Animal Industry to include also imported meat and poultry, inspection of domestic meat and poultry and related products, the conditions of slaughter, including humane procedures and a multitude of other duties by personnel of the Food Safety and Inspection Service. Other research activities that developed early in BAI have similarly grown as exemplified in the research of the Agricultural Research Service with animal husbandry, veterinary medicine, parasitology, and international programs, to mention examples.

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PART II
VETERINARY MEDICINE IN THE UNITED STATES DEPARTMENT OF AGRICULTURE

By

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Since 1884, veterinary medicine in the United States Department of Agriculture (USDA) has evolved from the Bureau of Animal Industry (BAI), with a single appointee, to today's large and diverse operations in three main areas—research, regulation, and inspection—with thousands of employees in large laboratories, in hundreds of commercial plants for livestock and meat production, in many small stations scattered throughout this country, and in several foreign lands. This brief account attempts to summarize the major events that affected the BAI and shaped its development, starting with the insistent demands of farmers from the 1850's to the 1880's that something be done to control animal diseases. After several studies of diseases were made under USDA supervision, Congress created the BAI. The brilliant accomplishments that followed established certain principles, or policies, for the control of diseases that still serve well today. We will describe briefly also a few of the early eradication campaigns and the research that preceded them, as well as the development of education and professionalism by and for the BAI veterinarians, and how those improvements permeated the profession at large at a time of profound social change.

When fundamental differences were perceived in its purposes and functions, the BAI was split into two, and then four agencies. We will illustrate this differentiation by examples of accomplishments in animal health and conclude with an overview of the major veterinary components of USDA that serve the national interests: long-term research and development work at large, modern laboratories; constant surveillance to prevent disruption of the livestock and meat industries by animal diseases; goal-oriented control programs working toward producer-selected goals; and emergency-action programs to combat outbreaks of animal diseases wherever they occur.

FROM THE BEGINNING

The BAI's principles of animal disease control are based on the scientific advances of the 19th century, particularly Louis Pasteur's germ theory of disease in 1880. Prior to the germ theory, diseases were ascribed to the evil eye, noxious effluvia, or visitation of Providence. The germ theory was quickly confirmed by an ambitious young veterinarian, Dr. D. E. Salmon, who was studying fowl cholera in the USDA in 1881. He recommended destruction of sick birds from any potential source of the infection, and preventive vaccination for control of the disease. Thus, the fundamentals of disease control predate the establishment of the BAI in 1884.

As animal diseases increased in destructiveness, farmers increased their demands for special efforts by the government to control the diseases. Reports by the agricultural division of the Patent Office, including the first Federal notice of an animal disease (hog cholera in 1860), and expressions of concerns by several agricultural and scientific organizations about disease losses—all contributed to the campaign for the establishment of the U. S. Department of Agriculture in 1862.

But USDA had no authority for veterinary service. In 1878, Congress appropriated $10,000 for studies on animal diseases by Drs. James Law and H. J. Detmer. Finally, in 1884, Congress established the BAI in response to demands from three main sources.

The first source was farmers needing help with rampant animal diseases. Contagious bovine pleuropneumonia was spreading toward the ranges of the West; mange and Texas fever were cropping up everywhere; anthrax, blackleg, and abortion caused heavy losses; horses had "big head" and glanders; sheep had scabies (mange), lockjaw, "blind staggers," and internal parasites; and losses in swine (mostly from hog cholera) were estimated in 1876 at $23 million. Despite the losses, the livestock industry grew in the 1870's to the extent that foreign markets were needed. Entrepreneurs began to ship live cattle to England for slaughter; carcasses were shipped under refrigeration; and

the Wilson Packing Company began canning pork for export. Butcher shops in London and Dublin were besieged by customers demanding American beef and pork because it was cheaper and better than the local product.

A second source of public demand developed when, in 1878, England and Germany banned the entrance of U. S. cattle, sheep, and meats on the grounds that they were infected with trichinae and foot-and-mouth disease. To learn the facts, the Commissioner of Agriculture, W. G. LeDuc, sent veterinarians to Europe. Although the allegations were dispelled, the restrictions were not removed. Our beef and pork were effectively excluded from European markets without good cause. But we had no veterinary force to cope with the problem.

The third precipitating factor in the creation of the BAI was two well-publicized problems of the meat industry—inhumane treatment of animals during shipment to markets, and the sale of meat from dead, crippled, and unhealthy animals. Although Congress passed laws to assure humane conditions for animals in cars and ships, and cities enacted regulations for the sanitary processing of meat for food, no one was empowered to inspect and enforce them. Dr. D. E. Salmon pointed out that some laws discriminated against healthy southern cattle.

In 1879, Congress became concerned about the importation of cattle. A Treasury Cattle Commission was created with Professor James Law of Cornell University in charge. But without authority to inspect ships and equipment, the results were described as "silly" and "ridiculous." Finally, in 1883, a veterinary division was created in the USDA and assigned to research on a 7 acre plot of ground on the outskirts of Washington, D. C. However, most agricultural leaders realized by this time that only a strong, vigorous agency could administer laws and regulations for nationwide disease control, and on May 29 of the following year, 1884, the U. S. Bureau of Animal Industry was established by an Act of Congress.

The First Chief of the Bureau

The first chief, Daniel Elmer Salmon who was born on a farm, received a good education at the Mount Olive, NJ, district school, the Chester Institute, and Eastman College. In 1868, he was a member of the first class of veterinary students at Cornell University, Ithaca, NY, where he was a student and friend of the newly appointed professor of veterinary science, Dr. James Law, an Edinburgh graduate. Because the clinical facilities at Cornell University were limited, Dr. Salmon was allowed to go to the Alfort Veterinary School near Paris for the last 6 months of his training.

In 1872, he received his bachelor of veterinary science degree, married Mary Thompson Corning of Ithaca, and began private practice in Newark, NJ. In 1876, Cornell University awarded him an advanced degree, the doctorate of veterinary medicine, and he became a nonresident lecturer in veterinary science at the University of Georgia.

In 1879, Dr. Salmon was appointed to the veterinary staff at Cornell University and with Professor Law participated in the program to eradicate contagious bovine pleuropneumonia from New York. By daily observations, he became thoroughly knowledgeable concerning the disease and methods to control it. When the appropriations for the program were exhausted in the fall of 1879, Dr. Salmon accepted employment with the USDA and began studying Texas cattle fever. In 1883, he was chosen to establish a veterinary division in the USDA, and in 1884 he was appointed chief of the BAI where he created the "first significant medical research institution in the United States" and promptly "applied laboratory results to a new dimension of veterinary medical practice—the herd or population dimension."

He developed the concept of geographic area or regional disease eradication, predicted that specific diseases would be eradicated from North America, personally directed the first federal campaign against contagious bovine pleuropneumonia, which was declared eradicated in 1892, and began to study projects on Texas cattle fever, dourine, glanders, hog cholera, fowl cholera, tuberculosis, and foot-and-mouth disease. Salmon also designed and implemented an improved system of animal import quarantine, and he laid the scientific foundations of a system of meat inspection which was initially the microscopic inspection of hog carcasses for trichinae. This system was based on federal laws which he had proposed and lobbied through Congress in 1891 and 1895. As a result of these laws, the BAI was expanded from a staff of 20 persons authorized in 1884 to more than 5,000 in 1915.

At 34 years of age, the new chief of the BAI was ready and willing to lay the foundation for years of research and administration. He was probably the first veterinarian in America with an understanding of the necessary components for adequate disease control. Certainly he was the only veterinarian to have done careful studies of bacterial diseases in animals. Salmon summarized the work of Pasteur and others on anthrax. "This being the entering wedge for the germ theory in scientific pathology, it is perfectly right to demand the most conclusive evidence before admitting it;

but this evidence has now been furnished—the germ theory has a substantial foundation—and medicine is destined to make its most brilliant triumphs by the discoveries to which it will lead. The progressive pathologist will waste no more time in criticizing what is so well established, but will press onward to other and equally important discoveries. We may confidently announce that the first story of the edifice has been reared upon the foundation, and that it is so well finished as to be perfectly safe for use, and to serve as a support for future work. It seems opportune, therefore, to present the evidences for the faith that is within us, so that all may see that we have a foundation clearly and firmly established."

Salmon understood the problems of epidemiology and medical science. "The importance to the farmer and stock raiser of a general knowledge of the nature of infectious diseases need not be insisted on, as it must be evident to all who have charge of farm animals. The growing facilities for intercourse between one section of a country and another, and between different countries, cause a wide distribution of the infectious diseases once restricted to a definite locality. Not only the animals themselves, but the cars, vessels, or other conveyances in which they are carried may become agents for the dissemination of disease. The growing tendency of specialization in agriculture, which leads to the maintenance of large herds of cattle, sheep, and hogs, makes infectious diseases more common and more dangerous. Fresh animals are being continually introduced which may be the carriers of disease from other herds, and when disease is once brought into a large herd the losses become very high, because it is difficult, if not impossible, to check it after it has once obtained a foothold. These considerations make it plain that only by the most careful supervision by intelligent men who understand the nature of infectious diseases and their causes in a general way can these be kept away. We must likewise consider how incomplete our knowledge concerning many diseases is, and probably will be for some time to come. The suggestions and recommendations offered by investigators may, therefore, not always be correct, and may require frequent modification as our information grows more comprehensive and exact."

Dr. U. G. Houck, chief of the Hog Cholera Division of the BAI and an unabashed admirer of Salmon, said: "It was fortunate for the livestock industry of the country that a veterinarian with the qualifications of Dr. D. E. Salmon was found to head the Bureau when it was first established. It was largely due to his keen perception in selecting able assistants, his ability as an organizer, his capacity as an executive, and, above all, his genius as an investigator, that the Bureau came so rapidly into prominence and has been able, independently and in cooperation with the States, to accomplish so many useful things."

Dr. J. F. Smithcors pointed out: "In some respects it might be considered fortunate that legislation establishing the Bureau of Animal Industry was sidetracked until Salmon had achieved sufficient prominence to become the logical choice for its first head. Fortunate, at least, that some considerably less able individual—who might have had a long tenure in this position—was not given the nod simply because he was available and earlier Salmon was not—a happenstance perhaps all too frequent, even today."

Salmon immediately surrounded himself with promising, well-trained young men: Theobald Smith in 1884; F. L. Kilbourne, 1885; Cooper Curtice and V. A. Moore, 1886; and E. C. Schroeder in 1887. All made notable contributions to the BAI record. Salmon established laboratories in the BAI, then in 1891 reorganized it into four divisions, an organizational form that continued until 1953. Thus, Salmon was a man of sound judgement and far-reaching vision. For 22 years, Salmon applied his principles and authority to fashioning the animal health program for this country; he was the most potent factor in making it the model for the world.

Salmon's administration was based on two fundamental principles: that veterinarians are responsible in a primary way for the control, prevention, treatment, and eradication of the diseases of animals, and for their comfort and humane treatment whether maintained for food, work, laboratory research, sport, or man's pleasure; and that with these responsibilities comes authority to prevent the introduction of foreign diseases with animals or animal products and emergency powers of quarantine and slaughter (depopulation) to extirpate foci of serious infections. As an active participant in the early laboratory investigations of fowl cholera and hog cholera and of field studies to determine the geographical limits of Texas cattle fever and contagious pleuropneumonia, Salmon established the style of research on infectious diseases that still serves investigators today: survey the problem and determine its geographical location, hosts, incidence, clinical signs, etc; bring the disease into the laboratory using a model animal, if necessary; and determine the causative agent(s). Salmon did not allow other problems to divert the BAI from research—one of his fundamental principles—and with his first assistant in the laboratory, Theobald Smith, M.D., studies were started on several animal diseases. Neither Salmon nor Smith knew much bacteriology, for neither had studied in Robert Koch's laboratory—the acknowledged source of information on bacteria and disease. Koch had recently shown a causal relationship between

a bacterium and anthrax—an important disease of animals and man. Louis Pasteur, in a dramatic and fortunate experiment in France, protected 23 of 24 sheep, 1 goat, and 6 cows from challenge by giving them attenuated (weakened) cultures of the anthrax organism. The prospect was alluring: artificial vaccination might be applicable to many, if not all, of the infectious diseases of animals! Chief Salmon, therefore, encouraged research as much as possible by providing laboratories, equipment, and foreign and domestic research journals; and he added staff as quickly as possible. The first study was designed to confirm the contagiousness of bovine pleuropneumonia. Research began on hog cholera and tuberculosis and expanded rapidly to include studies on abortion, glanders, blackleg, sheep scab (mange), and such diverse topics as tests for foot-and-mouth disease, dips for the destruction of cattle ticks, and tests of alleged curative nostrums. The work became so extensive by 1891 that Salmon created the Pathology Division for studies into the cause, nature, prevention, and treatment of diseases.

The BAI researchers were as productive as their European counterparts and Salmon soon had results that could be put into practice for disease control, justifying "the faith within us" of the imperative for laboratory research in advance of control and eradication measures. For the first few years, the chief of the BAI was able to assign new employees to new projects with minimal instructions, "Learn all you can about this problem." They gave him their results and the chief issued an Annual Report of the BAI. This happy management style didn't last long; organizational structure soon claimed its first victim: the brilliant Theobald Smith left in 1895 over personality conflicts.

As BAI research became more directed to defined goals with more plans and reports, the pursuit of knowledge was replaced with research for the sake of a practical goal; the BAI became a model of the bureaucratic style of management with distinct specialization of work, hierarchal discipline, job security, and the proliferation of rules, records, documents, and files. Time and attendance records became very important documents; conformity was expected. In the 1920's, a research veterinarian offended a BAI administrator by a minor transgression of a behavior rule; he was banished to meat inspection in Toledo for 2 years.

The first chief of the newly formed BAI had to mollify several groups of citizens making demands or political "hay;" e.g., "States' rights." The Act of 1884 did not give the BAI authority to quarantine livestock. In 1886, the Secretary of Agriculture conferred with State officials and issued rules for quarantine but they were not uniformly accepted; not until the next year did Congress provide adequate authority, penalties for willful violations of the regulations, and funds for indemnifying owners of diseased animals. The campaign to eradicate contagious pleuropneumonia convinced nearly everyone of the capabilities of the BAI, and of its good and equitable intentions, and thereby brought improvements in cooperation by State authorities. Relapses occurred, however, and the proponents of States' rights sometimes disagreed vociferously with Federal laws and regulations. In 1919, for example, several Kansas cattlemen prevailed over the BAI in a well-publicized incident. The men bought cattle in Fort Worth for their pastures in the "flint" hills of Kansas. After the BAI inspector declared them free of ticks and Texas fever, several of the cattle sickened and died soon after they were placed on the pastures. The cattlemen sued for $270,000 in Federal compensation on the basis of negligence by the inspector. After repeated hearings before congressional committees, a bill was passed in Congress allowing the suit, and eventually a Federal court in Kansas City awarded the men $251,000 in damages.

Similarly, the chief had to demonstrate fairness and good intentions toward the meat packers when Federal meat inspection was begun, because the "beef trust" had considerable political influence. Salmon adroitly trod a precarious path among the packers, the Congress, public officials, and his duty to safeguard the public health. In 1905, the vivid descriptions by Upton Sinclair of conditions in some meat packing plants precipitated Salmon's resignation and ended his career in the BAI. In 1906, Congress granted the BAI enough authority to do a credible job (see chapter on Meat Inspection).

Another "fire" that tempered the principles and practices of the young BAI was the long and acrimonious dispute over the etiology of hog cholera that involved Salmon personally and threatened his credibility and therefore the continued existence of the BAI. Until the viral etiology of the disease was determined by employees of the BAI in 1903, many claims of causation (and cure) were made. Dr. F. S. Billings, a German-trained veterinarian at the University of Nebraska, reported on certain bacteria that he thought were the agents of hog cholera, Texas fever, and cornstalk disease. He denounced everyone who disagreed with his own reports and particularly Drs. Salmon and Theobald Smith. In self defense, Salmon eventually proved that the investigations by Billings could not be relied upon, but not before doubts were created in the minds of many veterinarians and agricultural leaders. To meet the challenge, Salmon in 1888 was obliged to ask the Commissioner of Agriculture, N. J. Colman, to appoint a board of scientists to investigate the points at issue. After lengthy investigations, the board issued a noncommittal report.

The disagreements continued and intensified in 1891 and 1892. Dr. Austin Peters, chairman of the Intelligence and Education Committee of the United States Veterinary Association, made a long report to the Association wherein he bitterly criticized the BAI and its chief and attempted to sustain the claims of Dr. Billings. The questionable works and warped views of Billings and Peters were widely circulated; Salmon was concerned that they might be accepted as authentic by veterinary researchers everywhere. Because his work was denounced as a "forgery," Salmon defended himself and the BAI in a letter to the *American Veterinary Review*, pleaded for reasonable and fair criticisms, and admonished the profession to take care of its reputation and integrity.

The Association responded favorably to Salmon's statements; the criticism abated and studies continued for 15 years before the cause of hog cholera was established: a virus, a member of a newly discovered class of submicroscopic organisms. Salmon's name was not listed with the authors. In a later publication he said that "parallel experiments with pure cultures of *Bacillus cholerae suis*, which has heretofore been considered the cause of hog cholera, failed to produce characteristic cases of the disease." By his defense of the BAI against persistent and clever opponents, Salmon provided time for research, the results of which silenced the critics and established the BAI as a leading research organization. Salmon was elected president of the United States Veterinary Medical Association in 1897, and a large and important group of pathogenic bacteria, the Salmonella, are named in his honor.

It's difficult now to decide whether the rancorous criticisms of the BAI were a real threat to the existence of the young agency, but obviously the chief thought they were. However, stress only strengthened what it didn't destroy, and the BAI was stimulated to a flurry of activity in all existing areas plus many new projects in new divisions. As chief, Dr. Salmon was forced to analyze, discuss, and justify the fundamental goals of his agency and evaluate the means to be used in achieving them. BAI employees worked harder; they became extremely cautious and critical of their own research—that it was properly designed, that all "loopholes" were closed, and that each experiment was repeated in identical fashion enough times so the results were unquestionable. They made sure that all conclusions drawn from the results of an experiment were adequately supported by the data and that the interpretations of the data were cautious, restrained, and correct. For example, in studies on ticks as vectors of Texas fever, the veterinarian Fred L. Kilborne and Theobald Smith, M.D., divided part of the Experiment Station on Benning Road into four well-separated areas with "buffer states" between them and put experimental cattle into each—some with ticks from southern cattle, some with southern cattle but no ticks. The experiment was repeated each year for 4 years until the results were beyond doubt. Kilborne's proof of the role of the tick in transmitting Texas fever and Smith's demonstration of the actual causative agent were fundamental findings that showed the way to solving the old mystery of malaria, and by mosquito control, to the construction of the Panama Canal.

The innate caution and conservatism of the early BAI gave rise to another principle: skepticism of living vaccines, wherein the causative agent is alive, albeit supposedly attenuated. Although the BAI found heat-killed cultures of bacteria made good vaccines, many Europeans believed that only living vaccines immunized; e.g., rabies, smallpox, and anthrax. In 1891, the German scientist Emil von Behring developed a dried, attenuated culture of the tubercle bacillus for the immunization of young cattle against tuberculosis. When it was advertised for sale by a druggist in New York City, the BAI began tests on its safety, despite the international reputation of von Behring, his Nobel prize, and his peerage from the Emperor. Salmon and his colleagues quickly found the organisms in the udder and milk of vaccinated cows and they were fully virulent! After further extensive tests, the BAI in 1911 emphatically condemned the method as unfit for use in the control of tuberculosis in cattle. Numerous other living tuberculosis vaccines were advanced and tested by the BAI. All were rejected. In 1928, the American Veterinary Medical Association warned against the vaccine because it was not proved and it interfered with the tuberculin test, but several more years of work were required to convince the cattle and dairy industries to forego tuberculosis vaccination and agree upon eradication by the test and slaughter plan.

The BAI and its successors always tried to maintain close and friendly relations with livestock men and their organizations. Dr. Salmon believed the BAI should respond whenever possible to reduce losses caused by any disease that was widespread and therefore of national importance. When blackleg became a serious problem for cattlemen, the BAI responded by manufacturing the early vaccine developed at Manhattan, Kansas, and distributing it free of charge. The program began in 1897 and continued until 1922 when blackleg bacterin became readily available from commercial sources. As chairman of the Committee on Animal Diseases and Animal Foods of the American Public Health Association, chief Salmon encouraged sanitary practices for dairies until the city of Chicago in 1908 required that milk be pasteurized—a milestone in the battle against disease. The BAI repeatedly demonstrated its concerns for the problems of the stockman and the public health, and carefully nurtured contacts "down on the farm" through its field veterinarians and by participation in livestock organizations. The purpose, of course, was to monitor animal health at

first hand and detect disease outbreaks of national importance as early as possible. Nowadays, research personnel meet livestock producers at meetings of the United States Animal Health Association and other livestock producers' annual meetings where disease problems are discussed, research needs are identified, and control methods are agreed upon.

After many years of poor communications with the public, the agricultural press, and the world-wide scientific community, the BAI finally made dissemination of information a cardinal principle. From 1885 to 1915, results of BAI investigations appeared in the annual reports of the BAI. They were not reviewed for accuracy by other scientists and because the Reports were poorly distributed, many scientists learned of BAI studies only after they were reprinted, or abstracted, by the more popular journals of the day. Although major discoveries had been published in special circulars and bulletins, *The Journal of Agricultural Research*, established in 1913, provided a periodical medium for the dissemination of reports of veterinary research by USDA employees. Such reports now appear in the leading scientific journals.

The principles of disease control that Salmon applied as the first chief of the newly formed BAI were based on policies of the Veterinary Department in England, which had been created by the Privy Council in 1865 as a consequence of a disastrous outbreak of rinderpest in 1865-1866. Although the disease was epidemic in Poland, Germany, and elsewhere on the Continent, England temporized, first with restrictions on the importation of cattle and then with the outbreak, until rinderpest (cattle plague) became a threat to the national economy. The policies adopted by the Veterinary Department—"stamping out" as practiced on the Continent, had a dramatic effect in England; the cattle plague was soon suppressed and eradicated, and the Veterinary Department has continued until the present time.

Dr. John Gamgee was the most vocal English proponent of the "stamping out" policy for rinderpest, as well as foot-and-mouth disease, glanders, and contagious pleuropneumonia. He had spent two years on the continent and was familiar with the disease control measures that had held outbreaks in check except for those that followed major movements of cattle, usually during wars. In 1857, the brilliant Gamgee formed the New Veterinary School in Edinburgh and immediately began a crusade against the sale of meat from dead, crippled, or diseased cattle. Smithcors records the quite believable reply of Gamgee when asked by a continental colleague what England does with its diseased beef, "Eats it." He may have been the first advocate of specific-pathogen-free cattle, and his campaign for inspection to ensure hygiene in meat production was the progenitor of veterinary meat inspection in England and the United States.

In 1863, he wrote a letter to the London *Times* predicting not only the importation of cattle plague but that it would come from a Baltic port. In June 1865, rinderpest entered England, as predicted, from Russia via Baltic ports; it killed an estimated 300,000 cattle and from 1867 through 1871 stimulated several official acts for control of animal diseases. In 1868, Gamgee came to the United States to introduce a new process for preserving meat, and incidentally, he persuaded officials at Cornell University to appoint his former student, James Law, Professor of veterinary medicine and later head of the new veterinary department. D. E. Salmon was a member of the first class of veterinary students in 1868 and he became a friend of Professor Law.

Horace Capron, Commissioner of Agriculture, hired Gamgee to investigate Texas cattle fever. Gamgee was, therefore, the first veterinarian employed by the U.S. Department of Agriculture. His report, published in 1871, gave 12 possible causes of Texas fever. They were all incorrect. In fact, Gamgee ridiculed the "tick theory" advanced by some cattlemen.

But Gamgee had installed his principles of disease control in the American veterinary educational system, in the person of James Law, where they flourished and eventually bloomed with D. E. Salmon and the BAI. For example, Dr. Law wrote articles in the *Breeder's Gazette* urging more sanitary conditions in dairies and the end of inoculations against contagious pleuropneumonia by cow dealers. He contended that the disease could be eradicated and cited the example of Massachusetts where it was eliminated in 1864 and had not recurred. In 1887, Law was employed by the BAI and placed in charge of eradication work in Illinois; it was successful and induced increased activity in other States that had been lagging.

The English veterinarians John Gamgee and James Law influenced the policies of the BAI and these policies also were influenced by British authors—they wrote most of the textbooks—and by graduate veterinarians in private practice, most of whom had been trained in London or Edinburgh and had accepted Gamgee's ideas on disease control. Also, the BAI veterinarians read the British veterinary literature mostly because the first American veterinary journals did not appear until 1877 and 1880.

Another principle of the BAI was the recruitment of private veterinary practitioners to assist in programs of disease

control. Because many licensed practitioners were not graduates of a veterinary college, the BAI was forced to devise an examination for "accrediting" those who demonstrated suitable qualifications to do vaccinating and testing as assigned. Accredited practitioners were also authorized to brand reactor cattle, to quarantine them until shipment for slaughter only, and to appraise them for reimbursement under joint Federal-State indemnity plans. Only full-time BAI employees, however, were assigned to outbreaks of foot-and-mouth disease, but most of the calfhood vaccinations for brucellosis and the testing for tuberculosis and brucellosis were done by private veterinary practitioners under contract. In some cases, the fees received made it possible for a veterinarian to start a practice where it was impossible before. Because the United States is so large and the livestock enterprises vary greatly in different parts of the country, the BAI shared its responsibility for disease control with the States to varying degrees. Amicable relations were developed between the Federal bureaucracy, State officials, livestock producers, and private practitioners.

This brief summary of the development by the BAI of policies or principles for disease control reveals a variety of imperatives and pressures from the initial need to rescue the young livestock industry from plagues of disease, to trade restrictions imposed by foreign governments, to urgent needs for disease research and adequate communication with farmers, agricultural organizations, humane societies, members of Congress, foreign governments, and the scientific community. Many of the principles were of English or European origin. After the resignation of Salmon, subsequent chiefs modified and extended the early methods of disease control.

Other Chiefs in BAI

In 1905, Alonzo D. Melvin succeeded Salmon as chief of the BAI. He had been with the Bureau since 1886 and assistant chief since 1899. Thus, he had an active part in the developments until he was made chief in 1905. Concerning his appointment, the *American Veterinary Review* said: "Dr. Melvin enters upon his important duties with the entire good-will of the profession, and we trust his administration may be as successful as that of his distinguished predecessor." Melvin was born at Sterling, Illinois, on October 28, 1862.

After receiving the degree of Doctor of Veterinary Surgery from the Chicago Veterinary College in 1886, he immediately accepted a position with the BAI and was assigned to the eradication of pleuropneumonia of cattle. In 1890, he was sent to Liverpool to investigate certain phases of the export trade in livestock from the United States and in 1892 he was placed in charge of Federal meat inspection at Chicago. Three years later he returned to Washington, where he became chief of the Inspection Division. In 1899 he was made assistant chief of the Bureau and in 1905 he succeeded Salmon as chief and greatly expanded its activities. New divisions were established, such as the Meat Inspection Division in 1912; and the Tick Eradication Division and the Tuberculosis Eradication Division in 1917.

In 1908 and 1914, outbreaks of foot-and-mouth disease were so quickly stamped out under Melvin's leadership that he became well and favorably known throughout the Nation. He also was successful in the control of tick fever. In addition to his administrative work, he prepared manuscripts for many important publications. His activities in scientific and veterinary organizations are indicated by the fact that he was elected to the presidency of the American Veterinary Medical Association; he was honorary associate of the Royal College of Veterinary Surgeons; and was a member of the Board of the Hygienic Laboratory of the United States Public Health Service.

Melvin was found in 1901 to have tuberculosis. His colleague Dr. J. R. Mohler found tubercle bacilli by direct microscopic examination of sputum and by the inoculation of guinea pigs. Melvin went to Colorado for 4 years after which his disease was thought cured and he resumed his duties at the Bureau. For 9 years, he was apparently very healthy (he was over 6 feet tall and weighed 240 pounds). But suddenly he coughed up some blood and again Dr. Mohler found tubercle bacilli. Melvin slept on an open porch (considered excellent treatment at the time) for 3 years until he again decided to go to the mountains. But in December 1917, he died suddenly of pulmonary hemorrhage caused by tuberculosis. A resolution adopted by Melvin's colleagues in the BAI reads in part as follows: "In a more personal way he will always be affectionately remembered as a large-hearted, patient man, kindly, considerate, appreciative of the work of his subordinates who not only respected and admired him as their chief, but loved him as their friend."

When John R. Mohler became chief of the BAI 4 days after the death of Melvin, he was well informed concerning its activities because he had been taking a great deal of the responsibility during Melvin's ill health. Mohler was born in Philadelphia on May 9, 1875. He received the degree of Doctor of Veterinary Medicine from the University of Pennsylvania in 1896, then practiced veterinary medicine until he accepted a position as assistant inspector in the BAI in 1897. Two years later he became assistant pathologist and from 1904 to 1914 he was chief of the Division of Pathology.

As chief of the BAI (1917-1943), Mohler directed the activities of the largest group of veterinarians employed by any government—almost 2,000. In the campaign to eradicate bovine tuberculosis, they performed over 200 million tuberculin tests. They maintained and extended the meat inspection service and the tick eradication program; they discovered a practical stained antigen for the detection of pullorum disease in poultry, and they made many other outstanding scientific and practical contributions to animal health.

Dr. Mohler was a member and officer of numerous professional organizations. He was president of the U.S. Livestock Sanitary Association, the American Veterinary Medical Association (AVMA), and the International Veterinary Congress. Honorary degrees were conferred on him by Iowa State University, University of Pennsylvania, and the University of Maryland. He was cited as "scientist, investigator, administrator, eminent veterinarian, director of the work of more than five thousand Government employees, and leader in the eradication of animal diseases!" In 1939 he was awarded the Twelfth International Veterinary Congress prize, and in 1943, upon his retirement as chief of the BAI, he was the first recipient of the AVMA award. His death on February 12, 1952, terminated one of the most productive careers in the history of medicine. Mohler retired in 1943 after 46 years of faithful service with the Bureau, more than half of this time as its chief, and he was succeeded by Dr. A. W. Miller.

Arthur W. Miller was born September 27, 1876, at Manchester, NH. He grew up in Kansas and was graduated at the Kansas City Veterinary College in 1901. Dr. Miller retired in 1945 after 44 years of service with the BAI. His successor was Dr. B. T. Simms, Director of the Regional Animal Disease Research Laboratory/USDA at Auburn, Alabama; Dr. Miller was president elect of the AVMA at the time.

Bennett T. Simms was born at Emelle, AL, January 25, 1888, and graduated from Auburn University in 1911. After doing graduate work at the University of Chicago, in 1913 he became head of the Department of Veterinary Science at Oregon State College where he was widely known for his work on brucellosis, salmon poisoning in dogs, and in parasitology. He was secretary-treasurer of the Oregon VMA (1915-1938) and member of the state examining board, American Veterinary Medical Association delegate, and member of the Committee on Education (1919-1928). In 1944 he became president-elect of the Association, but because a regular meeting was not held in 1945, he served as president 1946-1947.

In 1945, Dr. Simms was appointed chief of the Bureau of Animal Industry and served in this capacity until the BAI was absorbed by the Agricultural Research Service (ARS) in 1954, whereupon he became chief of the Animal Disease and Parasite Research Division of ARS. Upon his retirement in 1957, he accepted a teaching and research position with the veterinary college at Ankara, Turkey. He died in 1964.

In the 70-year history of the BAI, there were only 5 chiefs:

D. E. Salmon, Cornell University 1884-1905
A. D. Melvin, Chicago Veterinary College 1905-1917
J. R. Mohler, University of Pennsylvania 1917-1943
A. W. Miller, Kansas City Veterinary College 1943-1945
B. T. Simms, Auburn University 1945-1954

With leadership of unusual stability, the agency was able to test, modify, and extend its policies and procedures for disease control and to conduct long-term research on the diseases of animals.

Veterinary Education

The BAI played a major role in the transformation of veterinary medicine from "a dubious, rustic art to a sophisticated biomedical science" by demanding better training for veterinary students and by participating in veterinary organizations and public health and humane movements. In the 1850's, a few trained veterinarians (the product of mostly English and German colleges) and hundreds of self-proclaimed "veterinarians" began to think of organizing, and veterinary associations were formed in Boston and Philadelphia. In 1863, the United States Veterinary Association was formed in New York City (the name was changed to American Veterinary Medical Association in 1898), and by the 1890's, most states had veterinary associations and laws governing the practice of veterinary medicine.

The first successful veterinary school, the New York College of Veterinary Surgeons, started in 1857. It was followed by 32 more before the end of the l9th century, thus transplanting veterinary education from Europe to the New World.

But standards were low: applicants were expected to be able to read and write but that requirement was waived at one school until the second year.

Despite numerous petitions to Congress for a national school for veterinarians, the United States lagged behind Canada, for example, in veterinary education, and the young BAI was unable to hire well trained scientists for its staff positions. In 1892, the National Veterinary College (NVC) opened in Washington, D.C. It was a private school staffed mostly by BAI veterinarians. Opposition to the NVC appeared immediately.

Criticism was directed toward the staff, headed by Dr. Salmon, and the term of instruction, 2 years, because efforts were under way to increase the term to 3 years. The National Veterinary College was not successful; only a few students matriculated, and it closed after 4 years of operations.

The BAI began its long campaign to upgrade veterinary education in 1894 when veterinary inspectors were placed within the Civil Service system; to be eligible for employment, the applicant had to be a graduate of a veterinary college. Over 800 veterinarians were employed by 1908 when candidates for BAI openings had to be at least 20 years old and have graduated from a "reputable veterinary college where courses in veterinary science should cover a period of 3 years of not less than 6 months of each year and a minimum of 3200 hours of instruction." Because of concerns about the quality of veterinary training, USDA in 1908 initiated an investigation of 19 veterinary schools. They were graded into groups: A (recommended to take the Civil Service examination) 11 schools; B (allowed to take the examination after 1898), 4 schools; and C (not eligible), 4 schools. Matriculation standards were raised also, to 2 years of high school in 1908 and to 4 years in 1916. In the 1930's, a year of preveterinary college work was added, and in the 1940's, 2 years were required so that veterinarians received a minimum of 6 years of college education. In 1918, the BAI was directed to maintain supervision of the work of the veterinary colleges; the program was continued until 1961 when it was relinquished to the American Veterinary Medical Association. From 1884 to the present, the BAI and its successors have had a significant role in upgrading veterinary education because it employed many veterinarians and had good working relations with the AVMA—no less than 6 AVMA presidents were BAI employees. At the present time, USDA is only one of many nonacademic influences on the education of veterinarians in the United States.

The BAI veterinarians actively supported the State and national veterinary associations and participated in many efforts to improve their profession. Dr. George C. Faville, for example, joined the BAI in 1887 and in 1894 was assigned to tick eradication in Virginia. He was immediately asked to help organize the Virginia Veterinary Medical Association, which he did, becoming a charter member. He later was elected secretary, and in 1931 he was the author of a history of the association. He took part in the expulsion of an officer for neglect of duties, supported resolutions against docking the tails of horses as "a cruel and barbarous practice," and, with the Association for the Prevention of Cruelty to Animals, brought charges against a blacksmith for burning a horse's mouth with a hot iron to cure the lampas (a rather common diagnosis by charlatans at one time). Many BAI veterinarians supported the American Humane Association and applauded its efforts to stop "wild-west" shows, bulldogging performances, and other cruel exhibitions. They also supported public health organizations. Dr. D. E. Salmon joined the American Public Health Association soon after it started in 1872, became chairman of the Committee on Animal Diseases and Animal Food, and was elected president of the Association for the 9th meeting (1881), which used the theme of veterinary medicine in public health. In 1947, Dr. B. T. Simms, chief of the BAI, actively supported the formation of the Division of Veterinary Public Health Service in the United States Public Health Service.

The BAI adhered to the highest standards of professionalism, also, in the campaign to extirpate tuberculous cattle from dairy herds. When the regular force of full-time veterinarians could not accomplish all the tuberculin testing, private practitioners were employed to test cattle in designated herds and areas. As chief J. R. Mohler explained at the 1922 annual meeting of the American Veterinary Medical Association, fully one-third of all licensed veterinarians had not been graduated from a veterinary college and did not have adequate training to administer and interpret the results of the tuberculin test. In order to protect the interests of livestock owners against incompetent veterinarians, the BAI arranged to accredit for the work only those practitioners who were able to demonstrate their proficiency by passing an examination. Not a single non-graduate veterinarian was ever employed by the BAI.

Veterinarians in private practice have played a vital role in augmenting the animal disease eradication duties of BAI veterinarians for more than 75 years. The "accreditation" by written examinations of veterinarians to officially represent USDA is a significant part of professionalism. In June 1907, the BAI established a list of practicing veterinarians registered to inspect and test horses for exportation to Canada. The original list included 63 practicing veterinarians in 12 States and was "limited to the actual needs of the work in that State."

In 1921, private practitioners were added to the team embarking on a nationwide program to eradicate bovine tuberculosis. They were needed to accelerate the initial testing. The practitioners were required to pass an examination administered by BAI to become "accredited." During the first year, 3,160 veterinarians were accredited in 31 States. When the program to eradicate bovine brucellosis was accelerated in 1934, private practitioners participated in the herd testing on a part-time basis. Although the name "accredited veterinarian" was first associated with the tuberculosis eradication program, the official duties of accredited veterinarians were, from the beginning, broader in scope. Standards for the performance of these duties were published in the Federal Register in 1967, and were expanded in 1974 to involve duties under the Horse Protection Act of 1970. Today, more than 27,000 accredited veterinarians in private practice perform official duties as representatives of USDA to protect the health and welfare of our livestock, poultry, and pets.

For many years, veterinary education and professionalism advanced steadily with the support of the BAI. Nevertheless, BAI veterinarians were grossly underpaid. In the early days, many of them taught night classes at veterinary schools or engaged in other enterprises to add to their income. In addition, they were unfairly classified under Civil Service regulations and were paid less than other employees such as bacteriologists. By 1928, chief J. R. Mohler noted that enrollment at the veterinary colleges had declined precipitously so that he despaired of replacing veterinarians who retired or resigned. Fortunateley, Congress enacted an extension of the Civil Service Classification System to include field employees—an action that resulted in larger salaries for many BAI employees. In 1934, Dr. Mohler addressed veterinarians on the 50th anniversary of the Association and to pay his compliments to the average Bureau veterinarian using words like *well-trained, professionally qualified, trusted, resourceful, adaptable, progressive, honor* and *personal integrity*. "I am hopeful," he said, "that these qualities, so well developed, will be continued."

RESEARCH AND ERADICATION PROGRAMS

Pleuroneumonia

Initial Challenge — When contagious bovine pleuropneumonia (CBPP) entered the United States in 1843, it was a major threat to the development of America's young livestock economy. A New York milkman, Peter Dunn, purchased an infected cow from the captain of the English vessel "Washington." A subsequent introduction took place in 1859 with the importation of four Dutch cows to a farm near Boston. The following spring, the Massachusetts legislature passed an Act providing for the appointment of three Commissioners to take measures to eliminate this new invader. The Commissioners were authorized to visit places where the disease was known or suspected, quarantine and appraise exposed and diseased animals, have the animals killed and buried, and have the premises cleaned and disinfected. By 1864, the disease was eliminated from the State of Massachusetts. With the introduction of the disease into Connecticut, policies were adopted that had proven successful in Massachusetts and the outbreak was likewise successfully eradicated. However, the State was reinfected through a movement of animals from New York.

The disease was introduced into New Jersey in 1847 by an importation but this initial introduction was controlled by the slaughter of the entire herd. Other infected cattle were later brought into New Jersey from the North and the infection spread to Pennsylvania, Delaware, Maryland, Virginia, and the District of Columbia. Partial efforts for the suppression of the disease were made by New York, New Jersey, and Pennsylvania but not Maryland and Virginia. The piecemeal approach by the States to suppress contagious bovine pleuropneumonia was not effective.

In February 1879, the British Government ordered that all American cattle arriving at British ports be slaughtered on the docks at the port of entry, thus lowering the price for American animals as compared to Canadian cattle—a loss of at least one million dollars annually. In addition, livestock owners and State and National veterinary authorities realized that contagious pleuropneumonia might spread to cattle on the vast plains of the West. The consequences of such a contingency would be devastating.

In 1882, George Bailey Loring, Commissioner of Agriculture, said, "The call upon the department for veterinary investigation during the year 1882 has been very great." His report continued: "To meet the calls which this state of affairs creates, I have been obliged to depend on such temporary and outside services as I could obtain. The absence of a well-organized veterinary division has been severely felt in the department, and it is of utmost importance that such a division should be established, in which all investigations can be directed by a competent head, and on which the owners of livestock can call for counsel and aid. It is important to know the precise extent of existing disease. It is important to know how to guard against the spread of contagion and how to provide for its removal." He concluded with the following sentence: "To do this a well organized division of veterinary inquiry and animal industry in this Depart-

ment is absolutely necessary." On May 29, 1884, an act of Congress was passed entitled "An act for the establishment of a Bureau of Animal Industry, to prevent the exportation of diseased cattle and to provide means for the suppression and extirpation of pleuropneumonia and other contagious diseases among domestic animals." The act authorized the appointment of a competent veterinary surgeon to be chief of the Bureau and a force that should not exceed 20 persons at any one time.

As chief of the BAI, Dr. D. E. Salmon took charge of the eradication of pleuropneumonia in cooperation with State authorities, and made a survey of the prevalence and location of the disease. Because many stockmen doubted that pleuropneumonia was contagious and opposed drastic measures for its eradication, an experiment was begun in September 1884 to demonstrate its spread; by January 3, 1885, 22 of 31 animals in the test had contracted the disease.

In July 1884, an infected cow was found in Illinois. The appearance of the disease west of the Allegheny forced the new Bureau to divert its attention to these outbreaks. Most of the States did not have adequate laws or funding to cooperate effectively and some were downright disinclined to enforce existing statutes. In March 1885, the disease was discovered in Missouri, but with active cooperation from the authorities, it was promptly eliminated.

A conference in 1886 convened representatives of New Jersey, Pennsylvania, Delaware, and Maryland and developed the first rules and regulations for combatting a disease; the rules were issued by the Secretary of Agriculture on August 2, 1886. In September of that year, contagious pleuropneumonia appeared in a dairy herd in the city of Chicago near the Union Stockyards, where cattle were passed to all parts of the country. To meet the emergency in the West and to facilitate the eradication efforts underway in the East, an act of Congress (March 3, 1887) appropriated funds and gave USDA authority to purchase and destroy not only diseased but also exposed cattle. Arrangements were made with the Illinois authorities to cooperate under this law. As a result, the spread of CBPP in Illinois was promptly checked and the last evidence of infection was destroyed in July 1887.

Eradication efforts around the area of original infection in Long Island and near New York City had been relatively ineffectual: pleuropneumonia had reappeared several times on the same premises. However, more radical measures were adopted early in the year 1889, and by the end of 1890 the disease was confined to areas around New York City and Jersey City. The last case was traced to the suburbs of Newark, NJ, on March 25, 1892. On September 26, 1892, the Secretary of Agriculture proclaimed eradication of contagious bovine pleuropneumonia from the United States. The program had cost the National government $1.5 million and required about 5 years to accomplish. In retrospect, if the States had had adequate laws and funds, the program probably could have been accomplished within 1 year. It is worthwhile to compare the figure of $1.5 million required to accomplish eradication with the annual loss of $1 million per year because of the embargo of beef to Europe.

The United States of America was the first of the large countries heavily infected with contagious bovine pleuropneumonia to achieve eradication. The accomplishment is particularly impressive if we recall that the causative agent had not been isolated or characterized, that the disease had a protracted incubation period of several months, and that serological tests were not available to assist in diagnosis. To carry out an initial eradication program with severe interruptions and restrictions of normal animal commerce required the application of unusual dedication, resolve, and skill. By accomplishing the paramount purpose for which it was created, the new BAI was a resounding success. The experience gained from the initial challenge was very useful in subsequent programs.

Swine Diseases

Hogs were introduced into the New World from the earliest times. Columbus brought them to the West Indies and De Soto shipped them into Florida in 1539. They were brought to the Virginia Colony in 1607, and in 1630, were in New England, where, according to Governor Winthrop, the wolves killed some. They apparently had no infectious diseases, and consequently multiplied very rapidly.

The early settlers brought hogs with them as they moved westward. By the 1840's, there were more pigs than people in the country (35 million versus 20 million). Large herds of pigs ran in the forest until fall when they were put in the cornfield to fatten for a few weeks before they were slaughtered at pork processing plants in cities like Cincinnati. The stage was set for an epidemic.

The disease we now know as hog cholera appeared in the Ohio Valley in the 1830's; the source cannot be established. It spread slowly for several years; by 1855, it was recognized in 13 States; by 1860, 22 States; and by 1887,

it was known in 35 States from Maine to Texas and California. Losses became enormous. An Indiana distillery lost 11,000 hogs in the fall of 1896.

The disposal of dead hogs was a problem for farmers. Because burning was a long and laborious procedure, most dead hogs were buried. But sometimes they were dug up clandestinely at night and hauled to a rendering plant where the carcasses were cooked and the lard used to make soap and axle grease. By 1901, dead hogs were quoted at $1.10 per hundredweight in Sioux City, Iowa. One buyer bought 92,000 pounds of dead hogs in 2 days. Another said he paid out an average of $1,000 a day for dead hogs delivered to his plant. When people complained about using soap manufactured from hogs that had died of hog cholera, a BAI veterinarian inspected a soap factory at Mason City, Iowa, and reported: "A hard frost having prevailed, the carcasses were all well preserved and stiff. In this factory I counted some 70 dead hogs piled up." He could not determine if any had died of hog cholera.

Early Studies—Research began in 1878 and numerous early studies were carried out; but neither cause nor cure of hog cholera was determined. After the establishment of the BAI in 1884, work on hog cholera under Salmon and Theobald Smith, M.D., the first chief of the Pathological Division, intensified, and in 1887, Salmon was able to announce the existence of "two diseases of hogs in this country which have heretofore been confounded as one plague." One motile organism was called the "hog cholera bacillus." It is now known as *Salmonella cholera-suis*—a pathogen of man and animals. Other bacteria were investigated. In France, Pasteur had prepared a vaccine against a plague of European swine called "rouget." It did not protect against the American disease. The BAI continued to study bacteria as causes of hog cholera—serums were made and tested and even field trials were conducted in Iowa, but the results were equivocal.

In 1897, the disease was very bad everywhere but especially in southwest Iowa. In response to urgent calls for help, the BAI dispatched a young researcher to test the latest antiserum on herds of Iowa swine. Marion Dorset was a small, gentle man with a limp and an M.D. degree (earned during night classes while employed by the BAI). He knew laboratory work but was completely ignorant of pigs. Dorset was only 23 years old when he arrived at night in Sydney, Iowa, armed with bottles of serum made in horses. He looked out of his hotel room window, then he went downstairs and asked the clerk, "What's the glare of all those fires out over the hills?"

The hotel keeper said, "Them's the fires of dead hogs that farmers can't do nothin but burn." The next morning, Dr. Dorset set out with his bottles of serum to save the Sydney swine herd. The farmers promptly held up their pigs for free shots of the serum to the "hog cholera bacillus." Several days later, Dorset returned to check on the results. They had all died, in spite of the shots, on all the farms.

The controversy was finally resolved in BAI laboratories by Emil de Schweinitz, a chemist, and Dorset when they secured a new filter from Pasteur's laboratory capable of retaining bacteria. They found that the hog cholera agent passed through the filter! In 1903, they reported that none of the bacteria championed by earlier investigators was the cause of hog cholera because they had transferred the disease from hog to hog by subcutaneous inoculations of fluids free of all bacteria. Although they could not know it at the time, they had demonstrated one of the first members of a new class of animal pathogens, now called viruses. This was reported the next year in *Report of the BAI* for 1904; Salmon's name was not included.

Dorset returned to Iowa in 1905 and began working in a small laboratory on the banks of the Skunk River near Ames. Two veterinarians, W. B. Niles and C. M. McBride, assisted him. They had learned that the disease was caused by a filterable agent. By 1906, the BAI knew how to immunize pigs using the serum from recovered pigs and a little of the blood of an acutely ill pig (the virus). The serum was collected from the tail; after the tip was washed and treated with a germicide, it was severed and the blood was collected in a clean dish. When the blood cells were removed, the serum was ready for administration with a syringe (Fig. 1).

Vaccination—The next year, over 2,000 pigs in 47 Iowa herds were vaccinated by the serum-virus method. That fall, all of the pigs that were vaccinated before the cholera came, survived the epidemic; but 89 of every 100 nonvaccinated, control pigs died. The results were so exciting that a demonstration of the method was promptly arranged for representatives of all the States of the Union. The method was patented and dedicated to the public; it saved the swine industry at the turn of the century and permitted its growth and technical progress.

Fig. 1. An early experiment by Dr. W. B. Niles at the Ames Hog Cholera Station. (a) Amputation of tip of tail. (b) Collection of blood for antiserum. (c) Injection of antiserum to protect a pig.

The dramatic developments caused much excitement among swine growers; they clamored for the serum, standing in line with pails outside the BAI laboratories. To expedite the development of an industry for production of the serum, the BAI began public demonstrations. By 1912, 30 States were distributing serum, which they either produced or purchased from the rapidly increasing numbers of commercial serum producers. It soon became evident that proper production controls were needed. A Kansas City physician, Dr. B. Nigra, for example, assumed quite logically that all market hogs were immune to hog cholera; so he arranged to collect hog blood at slaughter houses, bottled and sold it for the prevention of hog cholera. But it failed, of course, and the farmers were furious. In 1913, following passage of enabling legislation, the BAI initiated the inspection of serum production.

Area demonstration projects were continued and in 1914 covered 17 counties in various parts of the country. As could be expected, field results showed that serum alone was not as effective in preventing the disease as the administration of both serum and virus. These trials resulted in several conclusions, one being that the value of hog cholera immunization had been demonstrated and another—of considerable foresight—that eradication of hog cholera would require many years of effort and that no plan promising a reasonable hope of success could be suggested. By 1915, the swine industry was committed to a system of protection that offered insurance against devastating loss—a system that provided a way to "live with" hog cholera, but not a way to eliminate the disease.

The so-called simultaneous method (serum and virus) of vaccination was generally accepted by the swine industry. Serum production reached a half million milliliters (ml) in 1920; a billion ml was produced in 1927 (a bad hog cholera year) and production stayed over the billion ml mark in most years until the advent of the new vaccines in the 1950's. Vaccination greatly reduced the losses from hog cholera. By 1918, Secretary of Agriculture D. F. Houston reported that, "the death rate from hog cholera in the United States was 144 per thousand in 1897, 118 in 1914 and only 42 in 1917, the lowest in 35 years." When used by a majority of farmers in the intensive swine-producing areas, vaccination reduced the number of outbreaks and prevented the huge losses that had plagued the industry. But the method was not without problems. "Breaks" occurred, which were traced to a variety of factors; the procedure was costly; and, because millions of doses of hog cholera virus were insignificant—about 3 percent. They were to continue until the disease was eradicated in the 1970's.

Alternatives—The BAI continued to seek better and safer ways to protect hogs from cholera. In 1934, Dr. Marion Dorset, who 30 years earlier had been a co-discoverer of hog cholera virus and who had produced the first hyperimmune serum, used crystal violet dye as a virus-neutralizing agent with good preliminary results. Inactivated vaccines, however, did not confer prompt protection as did the old serum and virus treatment. Attenuated live-virus vaccines were developed next and were widely used in the 1950's. They differed in the degree of attenuation—some required the simultaneous administration of serum, and severe reactions sometimes occurred in pregnant sows, but they largely supplanted the serum-virus treatment. In 1954, Alabama banned the use of hog cholera virus. The time was ripe for a new look at the eradication of hog cholera.

Eradication—The BAI was formed for the suppression and extirpation of pleuropneumonia and other contagious diseases of animals. It succeeded brilliantly with pleuropneumonia, foot-and-mouth disease, dourine, and glanders. But a different approach was followed for cholera of hogs. Although an early eradication effort was made (it failed), and Congress specifically appropriated money in 1913 for eradication demonstrations, the BAI turned its attention to making better antiserum (by clarification and pasteurization) and to urging farmers to use serum and live hog cholera virus, thereby assuring the perpetuation of the disease.

After World War II, a new generation of swine growers using penicillin and other antibiotics began to produce thousands of hogs annually in confinement. They sold them under contract and by grade to be delivered on a specified day, perhaps to processing plants hundreds of miles away and across two or three States. The modern swine industrialist was intelligent, educated, aggressive, and progressive. Neither the threat of devastation by disease nor the imperative to vaccinate religiously was acceptable. If Canadian growers spent less than one cent per pig to keep their hogs free of cholera (after they eliminated the disease), why must American growers spend 45 cents per pig to live with cholera? The question, "Why not eradicate hog cholera?" arose among swine growers; the agricultural press picked it up, and the movement began.

In 1950, members of the American Veterinary Medical Association sent a resolution to the U.S. Animal Health Association stating that hog cholera could be eradicated and calling for a national committee to lead it. The next year, the association appointed 22 members from swine producers, veterinary research, farm organizations, the agricultural press, and State and Federal governments to formulate an eradication program and a massive national educational

effort. In 1956, the National Committee for Hog Cholera Eradication held regional workshops and publicized a nine-point program as follows:

- Eliminate virulent hog cholera virus
- Prohibit feeding of raw garbage to swine
- Require reporting of known or suspected outbreaks
- Quarantine infected premises
- Control movements of swine
- Clean and disinfect vehicles and infected premises
- Increase vaccination against hog cholera
- Intensify hog cholera research
- Institute a long-range information and education program

The first 6 points had been standard operating procedures in Canada for decades. By their presence, they emphasized the deficiencies in the American program of swine health.

In the spring of 1961 (10 years after the veterinary proposal), legislation was introduced in Congress for a national eradication program. The Secretary of Agriculture noted that hog cholera costs $40-60 million annually; the Act was passed and signed by the President on September 6, 1961.

Research in Diagnosis—Research people rallied to provide the tools for the eradication of hog cholera. The campaign had been launched with little knowledge of the incidence of the disease or of reservoirs of the virus, and worst of all, without a diagnostic procedure—a particularly knotty problem. For generations, veterinarians had been making diagnoses in cases of sick pigs using the history, clinical signs, necropsy findings, and common sense to arrive at prompt decisions so the waiting client could take steps to protect his herd if necessary. But the procedure was not accurate enough for research people or for such legal and financial actions as quarantine, indemnification, and depopulation. For use in the program, the diagnostic procedure must be practical, rapid, and sufficiently specific to be scientifically and legally supportable.

Research veterinarians and laboratory diagnosticians believed that test pigs must be used to confirm a diagnosis of hog cholera. Susceptible pigs must be given some of the suspected material; and they must be observed for 30 days for typical signs of the disease to provide the certain answer. Because such a delay was not acceptable in the eradication program, the National Committee for Hog Cholera Eradication turned to the American Association of Veterinary Laboratory Diagnosticians. Members of the Association quickly developed a systemic procedure for arriving at a diagnosis of cases of suspected hog cholera. They selected several diagnostic factors which were weighted according to their relative importance; they were herd history, clinical signs, pathological lesions and laboratory tests, e.g., hematology. At least one laboratory-type test was required to complete a positive finding. This could be met by a white blood cell count that could be carried out on the farm by a veterinary diagnostician equipped with a microscope. The procedure was proposed as a guide for diagnosis, leaving the final determination to the professional judgment of the veterinary diagnostician. This procedure was subsequently compared with suspect cases over a 6-month period. It was found that application of the factors resulted in agreement with the investigating veterinarian's diagnosis in 95 percent of the cases. The procedure was adopted, after final review, as a standard for use in the program.

This standard diagnostic procedure, modified as additional knowledge became available, was used throughout the field program. It was never seriously questioned—a credit to the small group of veterinarians who developed the original outline. It filled an urgent need at the right time and disposed of what could have been a major obstacle to a united program effort.

The diagnostic procedure was greatly strengthened by 1965 with the addition of a rapid and specific laboratory test—the fluorescent antibody procedure—with a diagnostic value equivalent to swine inoculation. This laboratory method had earlier been applied to other diseases. In general terms, it involves using a fluorescein dye to label specific antibodies produced by the body in reaction to infection with a specific virus. These labeled (dyed) antibodies, when attracted in quantity to a virus particle in the usual antigen-antibody reaction, can then be observed microscopically in a "clumping" pattern that can usually be differentiated from material not containing the virus.

In the early 1960's, work done at the University of Nebraska determined that this procedure might be applicable to the diagnosis of hog cholera. Scientists at the USDA's National Animal Disease Center—representing both veterinary

research and laboratory diagnostic activities—further studied and refined the techniques, including means for practical application to the field program. Tissue from a hog suspected of having hog cholera could be examined within hours after the sample reached the laboratory. In the hands of experienced people, the efficacy of the test was high—about 90 percent. Tonsil tissue, found to be a prime location for early detection of virus, could be obtained quickly in the field from the living animal.

These factors combined to promote rapid and widespread use of the test once it was approved by USDA for use in the hog cholera program. Later refinements of the test made it possible to locate obscure cases of the disease that might otherwise have gone undetected.

Throughout the eradication campaign, cooperation continued among veterinarians in research, diagnosis, and the field force. Research by USDA on hog cholera ceased in 1971; the last research report from the National Animal Disease Center concerned the yield of hog cholera virus in cultured cells after fusion by exposure to another virus (*Am. J. Vet. Res.* 33:121-125, 1972), but investigations continued in support of the campaign. In 1975, a report from the National Veterinary Services Laboratory concerned the transmission of hog cholera virus by mosquitoes *(Am. J. Vet. Res.* 36:611-614), and a study in 1978 determined the minimal temperature required to inactivate the virus in canned hams.

Thus, USDA veterinarians conducted research on hog cholera for 100 years—from the initial appropriation of $10,000 in 1878 to 1978. All studies are banned now. The only stocks of the virus are at the National Veterinary Services Laboratory and the Plum Island Animal Disease Laboratory; they are used only for surveillance and diagnostic purposes. Because hog cholera exists in Mexico, Veterinary Services is constantly on guard. If the virus were carried into our swine with some pork, for example, from Mexico or any one of several other countries, prompt detection and accurate diagnosis would be essential to curtail its spread and damage. To maintain and evaluate the capabilities of State and Federal laboratories to diagnose hog cholera, National Veterinary Services Laboratory periodically distributes test tissues for examination. At the present time, cultured swine cells or pork infected with the virus of hog cholera are irradiated (about 6.5 megarads from a cobalt 60 source) to inactivate the virus. If the tissue is kept frozen, the procedure does not alter its microscopic appearance, and the virus can be detected by the standard fluorescent antibody test. In this way, USDA maintains at least one diagnostic facility in each of the States with the ability to make prompt and accurate diagnoses of hog cholera should the disease enter the country.

Training—While research veterinarians were developing diagnostic tests, USDA began to train the field staff in their application. During 16 years of diagnostic training, 25 courses were conducted at the National Animal Disease Center (usually of 2 weeks duration) for over 400 State and Federal veterinarians on such topics as principles of virology and immunology, hematology, collection and transport of field samples for laboratory examination, clinical forms of hog cholera, and differential diagnosis. As additional knowledge became available, it was incorporated into the course. In 1963, laboratory training in the flourescent antibody test was added. In the late 1960's, chronic hog cholera and epidemiology were added. In the 1970's, veterinarians from many Central and South American countries participated in the diagnostic training courses.

Regulatory Actions—In 1961, USDA banned the use of hog cholera virus (several States had already done so), and gradually the movement of swine within and between the States was restricted. Feeding garbage was permitted only if it was heated to inactivate any hog cholera virus that might be in any meat scraps; USDA veterinarians regularly monitored the cooking process. During the first years of the campaign, the States did most of the work; owners of infected swine were reimbursed from State funds.

USDA began payment of indemnities in 1965, paying, during the campaign, a total of $25 million to owners of 5,700 herds.

Progress—Before the start of the eradication campaign in 1961, about 5,000 herds every year had clinical hog cholera. As USDA veterinarians moved into the field and confirmed each outbreak, the number of confirmed herd infections dropped to around 1,000 each year during the 1960's. It dropped to 100 in 1971, then to only a few herds until none was confirmed in 1977. On January 31, 1978, 16 years after the program began, the Secretary of Agriculture declared the U.S. "hog cholera free." Thus ended the largest eradication effort against a swine disease anywhere in the world.

The Final Case—The last isolation of hog cholera virus was made in 1976, from a sick pig in a herd in New Jersey.

The herd was one of 10 high-risk herds being fed garbage. Although the owner denied any purchases of pigs, the veterinarians believed the infection came from another herd in which some pigs had high antibody titers to hog cholera virus. Both herds and 6 other herds suspected of containing purchased swine were bled for serum neutralization tests and tonsil biopsies were done. Because of rising titers, all of the herds were destroyed. Hog cholera virus was isolated from one of these pigs at the time of slaughter.

It proved to be the final case of hog cholera in the United States during the eradication program. Surveillance was continued throughout 1977, with special operations in New England, New Jersey, and along the United States/Mexico border. During that year, 778 suspicious reports were investigated, but no cholera virus was found.

The entrance of an exotic disease provokes demands from American livestock men for its elimination; e.g., foot-and-mouth disease, Venezuelan equine encephalomyelitis, and exotic Newcastle disease of poultry. Hog cholera, however, had deep roots, supported by traditions, perceptions, vested interests, and a 50-year-old, official, control-by-vaccination program. All were swept away in the rush into modern swine production, and even the manufacturers of anti-hog cholera serum participated in their certain demise. The key elements in the movement were the following:

a. It was initiated at the grass roots—swine producers and their private veterinarians.
b. The National Committee contained strong, informed, dedicated leaders of most facets of the industry.
c. The program was phased, progressive, and flexible, and it emphasized education.
d. It was executed brilliantly by State and Federal veterinarians.

Economic Gains—The eradication of hog cholera cost the States and USDA about $140 million over 16 years. Since losses due to the disease were running about $57 million annually, economic gains were considerable; a cost-benefit ratio of $21 was described. Additional benefits include greater opportunity to trade in the international market and training of USDA veterinarians for control and eradication of contagious animal diseases.

Foot-and-Mouth Disease

Of the epizootic diseases of the world that are major constraints to efficient animal agriculture and barriers to international commerce in animals and animal products, foot-and-mouth disease is unique in that it is not characterized by a high mortality rate. It is a prime concern in countries where animal agriculture is highly developed with efficient management, sophisticated breeding programs, and high productivity to satisfy the market demands of the human population for animal products; but it is of lesser consequence in societies where animals are maintained and selected more for their ability to survive under harsh climatological and management influences.

Several features of the disease have resulted in its persistence and ability to move intercontinentally throughout the world and have made control particularly difficult. All cloven-footed animals, wild as well as domestic, are susceptible to the disease. There are at least 7 antigenic types of the virus with over 60 subtypes. Infection with one virus type leaves the animal fully susceptible to all others; as a consequence we are dealing with a multiplicity of diseases with common clinical characteristics. After infection or following vaccination, the period of protection is only a matter of months; if vaccination is to be carried out, it must be done on a sustained schedule for the major susceptible animal species of the country. Also, vaccination will be effective against only the specific virus subtype or subtypes contained in the vaccine. To compound the problem, it has been established that animals which have experienced the disease and have apparently recovered will still harbor infectious virus in the naso-pharyngeal secretions for years, making them carriers of infectious virus. As a result of these characteristics, vast sums of money have been spent to control the disease, particularly by the more affluent, highly productive nations of the world through means including development of better immunizing agents, maintenance of barriers to entrance of the disease into their country, and, should an accidental entry take place, use of effective means for the infection as rapidly and as effeciently as possible.

The viral agent of foot-and-mouth disease is one of the smallest known; it is highly invasive and is resistant to many of the chemical and physical factors that would inactivate other disease-producing agents. Sophisticated laboratory facilities and highly trained scientific staff are required in order to carry out diagnostic and vaccine production activities. In addition, other viral diseases produce clinical signs that resemble foot-and-mouth disease—diseases including vesicular stomatitis, vesicular exanthema of swine, and swine vesicular disease, the first two of which have occurred in the United States. Because foot-and-mouth disease is a constant threat to our livestock populations and wild game animals, veterinary authorities place the highest priority on being able to deal effectively with an incursion of this infection.

The first outbreak of foot-and-mouth disease in the United States was in 1870. There were subsequent outbreaks in 1880, 1884, 1902, 1908, 1914, and 1924, with the last minor outbreak in California in 1929. With the exception of the 1914 outbreak, all were of short duration and limited to small areas. The 1908 outbreak was traced to contaminated smallpox vaccine imported from a foreign country. In another outbreak, the virus was carried from a serum-producing plant to five States. It resulted from the release of contaminated anti-hog cholera serum which was obtained from hogs not showing lesions at the time of slaughter. The initial case in the 1924 outbreak was traced to garbage containing meat scraps from foreign countries. Outbreaks occurred in Texas also in 1924 and in 1925. In 1929, foot-and-mouth disease appeared near Los Angeles; it was associated with garbage offloaded as sea stores from foreign ships. As a result of these multiple experiences with the disease, Congress authorized the appointment of a commission, which visited Europe in 1925 and observed the programs and policies of 11 European countries with extensive experience in dealing with foot-and-mouth disease. In June 1930, The "Tariff Act of 1930" was approved by Congress; it imposed an embargo against the importation of cattle, sheep, other domestic ruminants and swine, and fresh, chilled, or frozen meat from such animals from any country known to harbor rinderpest or foot-and-mouth disease. The United States has not had an outbreak of foot-and-mouth disease in the national herd since the Act was passed.

To keep the North American continent free of foot-and-mouth disease, the Mexico-United States Agricultural Commission was organized in 1944. During subsequent discussions, cooperative programs were developed for eliminating outbreaks in either country. In 1945, a shipment of Zebu bulls was authorized to enter an island quarantine station off the coast of Mexico as a result of considerable pressure from both U.S. and Mexican cattle interests. The apparent success of the movement of these animals led to a second shipment in May of 1946. After their release from quarantine to the mainland of Mexico, positive identification of foot-and-mouth disease was made on December 26, 1946, and the Mexican border was closed in compliance with the Tariff Act of 1930. The subsequent program by United States and Mexican veterinary authorities is one of the finer examples of international cooperation against a highly destructive social and economic burden, not only to the affected countries, but to the region and continent as a whole.

On February 27, 1947, the Secretary of Agriculture was authorized to cooperate with the Government of Mexico in eradicating the disease before it crossed the border. He appointed an advisory committee and the Mexico-U.S. Commission to eradicate foot-and-mouth disease was formed on April 2, 1947. The Commission had a director from Mexico and a co-director from the U.S., with offices located in Mexico City. The country was divided into districts with U.S. and Mexican inspectors working side by side. The original program required slaughter and burial of infected and exposed cattle, quarantines, and disinfections. In November 1947, the program was reinforced, with greater emphasis on cleaning and disinfection of exposed premises and vehicles, control of the movement of cattle, and use of vaccines. Initially, it was necessary to import vaccines from other countries until production was initiated in Mexico in May 1948, when spread of the disease was stopped. Vaccine production was discontinued (April 1950) and the vaccination of cattle ended 6 months later. Several small outbreaks occurred subsequently in Mexico; the last infection occurred in May of 1953. Since that time, the Mexico-U.S. Commission for the Prevention of Foot-and-Mouth Disease has continued its collaborative efforts in identifying outbreaks of disease requiring differential diagnosis.

In February 1952, foot-and-mouth disease was officially diagnosed in Canada. The disease was introduced by an immigrant from an infected farm in West Germany who had been employed on the Canadian farm for a period of only 3 days. Ten days after he had left the farm, the owner noticed that his pigs were off feed and salivating. Apparently, the immigrant had carried in his baggage meat or meat products derived from infected animals. The disease occurred in central Canada during extremely cold weather, which restricted the movement of people and animals. Since the virus survives freezing temperatures, additional cleaning and disinfection procedures were necessary when warm weather appeared. After an intensive and highly successful eradication campaign (42 premises with 1,700 cattle were involved), followed by a waiting period, U.S. restrictions against importation of livestock from Canada were lifted on March 1 of the following year.

Eradication of this outbreak of foot-and-mouth disease cost the Canadian Government $1 million. In addition, cattle exports to the world market were eliminated, the cash value of Canadian livestock dropped $540 million, and the government paid compensation of several million dollars to farmers. This small outbreak involving only 42 premises, therefore, cost a total of approximately $800 million.

The Secretary of Agriculture was authorized by Congress in 1971 to develop cooperative agreements, with the countries of Colombia, Panama, Central America, Mexico, and the Caribbean area, on communicable diseases of livestock and poultry because of the imminent construction of the Panamerican Highway linking a continent infected with foot-and-mouth disease with the countries of North America that had been able to maintain freedom from the disease.

The ministries of agriculture and animal health officials of the respective governments promptly endorsed the proposal. At the request of the U.S. livestock industries, the National Security Council advised that no more U.S. funds should be expended on the Panamerican Highway until Colombia had organized a program that would assure control of the disease and until a zone free of foot-and-mouth disease was established in portions of Colombia along the route planned for the highway.

Countries that have been able to maintain freedom from foot-and-mouth disease uniformly agree that it is best to use the drastic "stamping-out" method for dealing with the disease in a fully susceptible livestock population. It is recognized, however, that in the event of an outbreak involving a large percentage of the population or a large geographical area, the public may not be willing to adhere to the strict controls essential for limiting the spread of the virus or abide by the restrictions on commerce and movement that are necessary to "stamping-out." In order, therefore, to establish a fall-back position, if it became politically necessary to do so, a tripartite agreement was drawn up between Canada, the U.S., and Mexico to utilize vaccines.

In 1952, Congress appropriated $10 million to build the Plum Island Animal Disease Laboratory off Long Island, NY, to carry out research, primarily on foot-and-mouth disease, but also on other diseases of foreign origin that threaten the livestock industries of this country. Scientists at the Laboratory (later identified as the Plum Island Animal Disease Center), have developed a high degree of competence in diagnosis and research on viruses.

Vesicular Exanthema

The elimination of a biological entity from the world is a rare and unique situation but it may have been accomplished with the elimination of vesicular exanthema from U.S. swine in 1959. When vesicular exanthema was first observed in 1932, it was thought to be foot-and-mouth disease; the affected animals were slaughtered and burned. Nevertheless, the infection persisted in swine in southern California for several years. In 1944, for example, approximately 430,000 animals were involved—more than 40 percent of the State's swine population. Epidemiological investigations focused on the fact that raw pork trimmings and uncooked garbage were a source of virus when fed to swine. Control efforts were directed toward making it mandatory to cook garbage in order to inactivate the virus. Infected swine in the early stages of the disease show no signs of the infection and consequently can be marketed without being detected. Scraps of pork from these animals or from other infected, exposed, or recovered swine might be thrown into the garbage of restaurants, institutions, hotels, and households. Discharges from swine in the early stages of the disease, or recovered swine, also are infectious.

The disease remained confined to California until late 1951, when a passenger train carrying uncooked pork from San Francisco, contrary to Federal law, did not leave the pork trimmings in the State of California; the meat was trimmed when the train was en route and the trimmings removed in Wyoming. They were bought by a rancher who fed them raw to his swine and initiated an epizootic in the United States that did not end until late in 1956. It involved 40 of the 48 States and cost the Federal Government $33 million. In response to the sudden and widespread appearance of vesicular exanthema in swine, an emergency program was devised between the Federal and State Governments including quarantine, prompt disposal of infected and exposed swine, cleaning and disinfection of infected premises, inspection of animals in and around known infected or suspected areas, a prohibition on the feeding of raw garbage, the control and monitoring of garbage-fed swine, and the distribution of accurate, helpful information. It was essential that garbage be heated to at least 212° F for 30 minutes to destroy the virus and break the cycle of its dissemination, and that all vehicles and facilities used for transporting swine be cleaned and disinfected.

A major reason for the success of the program was broad dissemination of factual information relating to vesicular exanthema. This dissemination required close communication with not only representatives of the industry but also with policy makers of the respective legislatures. After the last case made its appearance in Secaucus, NJ, in late 1956, it was considered necessary for a surveillance period of 3 years to elapse before the Secretary of Agriculture could declare that vesicular exanthema of swine was an exotic disease. The disease has been found only in the United States with two exceptions. It appeared once in Iceland as a result of shipping pork products to military forces stationed there and it was eradicated; and it appeared once in the dock area of Hawaii in materials of animals shipped from California, and also was eradicated. Therefore, with all of the epidemiological surveillance carried out in the 3-year interim, it was appropriate to declare that vesicular exanthema of swine had been eradicated from the planet in 1959.

However, tenacity for life in biological systems is impressive. In 1972, studies were carried out on abortions in sea lions on San Miguel Island near Santa Barbara, California. Approximately 150 samples of tissue were inoculated into

cell cultures; 7 viruses were isolated. One of the isolates closely resembled vesicular exanthema virus and it was identified as San Miguel sea lion virus. It produced clinical vesicular exanthema in swine and was placed in the calici virus group. In addition to the isolate from sea lions, additional isolates have been made from northern fur seals collected from the Pribilof Islands; the isolutes were serologically identical to San Miguel sea lion virus.

In viewing the early (1932-34) outbreaks of vesicular exanthema in swine, it was learned that some garbage fed to swine came from restaurants known to have sea food on their menus. Because sea lions sometimes interfered with fishing by scaring off schools of fish, they were sometimes caught and the carcasses sold to hog ranchers for swine food—the potential source of the virus for the earlier outbreaks in swine.

A vesicular disease in swine causes concern in USDA and requires a rapid and accurate diagnosis to verify the existence of an exotic disease such as vesicular exanthema, swine vesicular disease, or foot-and-mouth disease. There are 13 immunologically distinctive types of vesicular exanthema virus; the plurality of immunological distinct types and the ease with which virus mutates complicate the diagnosis of the disease. Only convalescent sera retain their type specificity; hyperimmune sera are not typespecific and may react with other antigens, but not the viruses of foot-and-mouth disease or vesicular stomatitis. The Plum Island Animal Disease Center is one of the very few laboratories in the world able to conduct a definitive identification of these viruses.

Screwworms

For 150 years, screwworms ruled the cattle industry of the South and Southwest. Every spring the adult flies came north from their warm sanctuaries in Mexico, laid their eggs on every wound, however slight, of all animals, domestic, wild, captive or pet, and even humans. Within hours, the eggs hatched into larvee (the so-called maggots) and burrowed in the living tissues, causing infections, pain, and death. Livestock producers could not brand, dehorn, or castrate cattle during that season of the year when screwworms were severe; even minute lesions from ticks were "blown." Losses were especially severe in newborn calves and fawns.

In 1938, E.F. Knipling, a USDA entomologist, proposed a new way to control screwworms that might prove applicable in the control of other pests. Knipling's idea was to rear insects in huge quantities, sterilize them sexually, and release them in infested areas to mate with normal insects. From such matings, there would be no offspring, and if enough sterile insects were released the species would breed itself out of existence. With R. C. Bushland and BAI veterinarians, the idea was tested on the island of Curacao off the coast of Venezuela. In 6 months, screwworms were completely eradicated from the small island.

Cattlemen in Florida immediately demanded the same treatment for their area. A "fly factory" was established at Sebring, FL, to rear 50 million flies a week on low-grade horse meat and blood. The breeding colony of flies deposited eggs in specially prepared racks. The eggs were removed and, 100,000 at a time, were placed on moist paper in a "hatchery." The tiny larvae emerging from the eggs were placed in starting trays for a day and then transferred to rearing trays of ground meat and blood. As the larvae grew and matured (in about 5 days), they crawled off the media into troughs, where they were collected in trays of sand to pupate. When the pupae were 5½ days old, they were sexually sterilized by a brief exposure to radioactive cobalt-60. Just before it was time for the flies to emerge, the pupae were run through a small machine that automatically discharged them into small cardboard boxes—400 to the box—to be dropped from airplanes. These flies were all sterile but not radioactive. As each box was ejected from the plane, a mechanical device opened the box so the flies would escape and begin their search for mates. Small planes carried 1,000 boxes each. Screwworms were eradicated from Florida in 18 months. Then cattlemen in Texas agitated for the program. When the Texas legislature refused to provide funds, members of the Southwest Animal Health Research Foundation contributed more than $1 million to match Federal funds, in order to get the campaign started in Texas. The Secretary of Agriculture announced the beginning of the cooperative program on February 3, 1962, with a budget of $3 million.

The "fly factory" for the Southwest was located at an abandoned Air Force base near Mission, TX. It had double the capacity of the Florida plant and many refinements in equipment and production methods. At peak capacity, it could produce 100 million flies a week from nearly 60 tons of ground meat, 6,000 gallons of blood, and 17,000 gallons of water. According to USDA veterinarians, the program cost $12.5 million, but by the end of 1964, the screwworm had been eradicated from the United States, except for small areas in Arizona and California; these States were later freed of the pest.

What had seemed an almost impossible task was accomplished through the excellent cooperation of the livestock industry and State and Federal regulatory forces. This campaign, which went much further than had been anticipated, involved high officials from the Republic of Mexico, who took the responsibility of permitting U.S. planes to fly over a large area in Mexico, dropping flies to establish a barrier zone so screwworm flies could not come up from the south and nullify the efforts north of the border. The barrier zone is now about the middle of Mexico, or halfway to the goal—the Isthmus of Tehuantepec, where the country becomes much narrower and the zone will be less costly to maintain. Research continues at the Mission, TX, station to meet emerging problems of the screwworm program; e.g., the development of resistance to irradiation.

Tuberculosis

The role of the BAI in the control and eradication of tuberculosis in animals was facilitated by the discovery in 1890 of tuberculin, which made it possible to diagnose the disease in cattle; even apparently healthy cows reacted to the test antigen and some were found to be excreting tubercle bacilli in their milk. The BAI soon learned how to distinguish bovine and human tubercle bacilli, and developed proof that organisms from cattle caused tuberculosis in humans. In 1893, a BAI veterinarian, E. C. Schroeder, applied the Koch tuberculin test to a herd of cattle near New Charlotte, NY. Fifteen of 34 animals reacted; 13 of them were found to have typical lesions of tuberculosis at necropsy. When the rest of the herd was slaughtered, two of the nonreactor cows had lesions. Dr. Schroeder reported that the absence of reaction to tuberculin did not constitute proof that an animal was not tuberculous. The State of New York in 1909 passed laws requiring that reactor cattle be branded and that records be kept of the production and sale of tuberculin.

At first, tuberculin was administered by subcutaneous injection; a rise in body temperature for 12 to 24 hours was the diagnostic reaction. Because confining cattle during hot weather was unacceptable and range cattle could not be easily restrained for temperature readings, the French skin method developed by Charles Mantoux, M.D., was quickly adapted to cattle by BAI veterinarians; it became the official test in 1920. The diagnostic reaction was a localized skin reaction; checking for a rise in body temperature was not necessary. The intradermal (skin) test saved much time and labor in administration; because it was cheap and reliable, national eradication of tuberculosis was feasible.

At the turn of the century, the incidence of tuberculosis in cattle ranged from 4 percent in Vermont to 50 percent in Massachusetts with 100 percent infection in many herds. City health officials and livestock officials of several States made spasmodic attempts to eliminate tuberculosis from cattle (particularly dairy herds), but little of an enduring nature was accomplished. An exception was the District of Columbia where BAI veterinarians reduced the incidence of bovine reactors from almost 20 percent in 1910 to less than 1 percent by 1917. In that year (1917), the Tuberculosis Eradication Division was established within the BAI by its chief, Dr. A. D. Melvin.

Early Control Efforts—As early as 1900, Dr. Salmon suspected that imported purebred cattle were bringing tuberculosis into our best cattle herds. He required that they be tuberculin tested on arrival in this country. When importers suffered losses due to reactions, Salmon assigned the first BAI veterinarians to overseas posts to test cattle intended for importation into the U.S. Of the first 1,000 tested, 64 cattle were rejected. The BAI in 1923 began a requirement that animals being shipped to the United States must be accompanied by an official report of a satisfactory tuberculin test from a veterinarian of the government of origin. The animals must be retested by BAI veterinarians after they arrived in this country. Similarly, any animals to be exported from the United States must be officially tested for tuberculosis by government veterinarians.

In an effort to reduce tuberculosis in the children at Indian schools, the BAI in 1909 began tuberculin testing the dairy herds on reservations in several States. Thirty-one herds were tested; all reactors were removed. The schools were assured their milk was free of tubercle bacilli. At BAI urging, the management of livestock fairs began to require tuberculin tests for cattle; in 1921, the Iowa State Fair required that all cattle be from tuberculosis-free herds.

Herd Accreditation—The BAI evaluated a great array of proposals for testing, immunizing, and curing cattle of tuberculosis before adopting the test and slaughter method for eradicating the disease. Of all the schemes, the methods the BAI developed for the District of Columbia offered the most hope for success. The District enacted regulations as follows. After January 1, 1908, (1) all cattle must be tested with tuberculin; (2) the reactors must be removed; and (3) no bovine animal can enter the District if it reacted to the test. On the first test, almost 20 percent of all cattle in the District reacted; in 1925, none reacted. The first "accredited as free of tuberculosis" herd was at Garrett Park, MD, on April 27, 1908.

Tuberculosis Eradication—Organizing began in 1916 for the eradication of tuberculosis and the next year Congress appropriated $75,000. In 1918, a conference was held in Chicago attended by representatives of the BAI, cattle registry associations, meat processors, producer associations, the agricultural press, 35 State veterinarians, and others. Public support developed quickly after that. Most States enacted enabling legislation and Congress appropriated $1.5 million for the program. This program was truly national. Every cow in every herd, on every farm, in all the States was to be tested by subcutaneous inoculation of the diagnostic reagent and examined 72 hours later by palpation of the site (at the base of the tail usually) for a "reaction"—a firm swelling the size of a pea or larger. Previous campaigns were localized, shorter, and more intensive. This one had no target date for completion. In order that veterinarians, farmers, and others have complete and up-to-date information, special courses and conferences were held. Bulletins on tuberculosis were prepared by the BAI. Postmortem demonstrations were held for farmers. Newspapers, radio and the agricultural press all cooperated to educate the public about the program and to secure appropriations from the State legislatures. As individual herds in an area were certified as tuberculosis free, the area was certified. Clay County, MS, became the first to complete testing; 17 counties in 4 States were modified tuberculosis free in 1923. This was the beginning of the greatest program for tuberculosis control in recorded history! Only 20,000 cattle were tested in 1917. In 1929, 11 million were tested and the peak was reached in 1935 when BAI veterinarians administered tuberculin to 25 million cattle! During this time, the reactor rate declined from 3.2 percent to 0.5 percent. Owners were indemnified by State or Federal funds. In 1928, the entire State of North Carolina was declared modified accredited, and in 1940, the goal of the BAI was reached when the last State, California, was declared accredited. The success of State-Federal tuberculosis eradication programs has been such that in recent years there has been some reluctance to spend sufficient money to continue these programs at the required level. Complacency, in a belief that bovine tuberculosis is no longer a problem, has resulted in a sharp rise in the number of cases in some States and severe outbreaks in some herds. Control of such problems requires an epidemiologic survey to locate the source of the infection and repeated tuberculin tests to eradicate it.

The TB "War"—A few farmers in eastern Iowa organized in early 1931 to oppose compulsory tuberculin testing of cattle. When the objectors interfered with the testing of five herds in Cedar County, the herds were quarantined. Later, the State veterinarian, 20 police officers, and other officials were prevented from testing a herd of cattle by almost 1,000 angry farmers. The protest then continued at the State capitol, but both the legislature and the Iowa Supreme Court upheld the laws.

Another attempt to test the cattle was made in April, but violence ensued; the veterinarian was evicted by angry farmers brandishing pitchforks and other officials were thrown into the watering tank. The protest ended in May when the National Guard appeared on the scene; the tests were performed by veterinarians chosen by the farmers. The protest movement then moved to South Dakota and California; the program was delayed and those States were the last to be accredited.

Tuberculosis in Animals Other than Cattle—During the time when bovine tuberculosis was being virtually eradicated, the BAI was also concerned about the disease in swine, chickens, and some other animals as well. Most of the swine infections originated from chickens; control was accomplished by keeping swine separate from poultry. Control in chickens was achieved by disposing of chickens before they reached 2 years of age.

Avian Leukosis Complex

The BAI established a research laboratory at East Lansing, Michigan, in the 1930's to find ways of curbing losses in the poultry industry. One of the problems was called the avian leukosis complex—a group of tumors and blood diseases called "big liver disease," "grey eye," and "range paralysis" by poultrymen to identify the main forms of the clinical disease. After years of controversy, most people now distinguish Marek's disease (first described by the Hungarian veterinarian in 1907) from an assortment of lymphoid tumors and blood diseases of chickens, turkeys, ducks, and many other avian species. When the poultry industry began to raise very large flocks under crowded conditions in the 1950's, Marek's disease became a major cause of deaths of birds and of condemnations for tumors by USDA inspectors at slaughter houses.

Under modern rearing methods, chickens have more tumors than any other animal; among laying hens and broiler flocks, losses of 50% were not unusual. In the absence of any scientific knowledge of the cause and control, many remedies were proposed: vitamins, potassium iodide, tomato puree, krebiozen (a substance from horse serum), and various secret formulas. But nothing was effective.

During the 1950's and 1960's, knowledge accumulated on Marek's disease at the USDA veterinary research laboratories and at other laboratories. The breakthroughs came in 1967 when English workers reported the isolation of the causative agent—a herpes virus. One of them quickly developed an attenuated vaccine, recognized the economic value of his discovery, and started a company to manufacture the vaccine.

The causative agent was discovered independently the same year (1967) at the East Lansing laboratory, but because the ARS group chose to publish in a slower journal, their report did not appear until 1968 (the reports were received for publication within 10 days of each other!). The work intensified at East Lansing. During studies on the transmission of the virus, every organ of diseased chickens was examined; the virus, veterinarians learned, matured to infectious form only in the feather follicles of the skin. As feathers grow, they shed dander, and that is the route of elimination of the virus.

Marek's Disease

Vaccination —After the causative agent was identified, research on Marek's disease quickly turned to control by preventive vaccination.

The English vaccine was not licensed by APHIS for use in this country; the data were not sufficient to overcome the deep-seated aversion to supposedly attenuated causative agents. Turkeys and other birds were examined by the East Lansing workers to see if they were the natural reservoir of the disease in chickens. From Indiana turkeys submitted by a practicing veterinarian, a herpes virus was isolated that did not kill chickens but was very closely related to the virus of Marek's Disease. Workers at the University of Wisconsin also isolated herpes viruses from turkeys but they did not exploit the discovery.

The ARS group at East Lansing quickly recognized the possibility that the turkey virus might protect chickens from Marek's disease. For the vaccine effort, Drs. H. G. Purchase and W. Okazaki were directed to organize and conduct a research program that would in a single year prove the efficacy of a vaccine and provide sufficient data to satisfy the requirements of the Biologics Division/APHIS. The assignment was fulfilled through the dedicated efforts of many members of the laboratory staff; Dr. Purchase remembers it as, "The most exciting and rewarding time of my life." The vaccine was licensed by the State of Michigan in November 1970 and by the APHIS in March 1971. At about the same time, Dr. C. S. Edison, working at the Poultry Disease Research Center, University of Georgia, used the turkey virus to vaccinate over 3 million chickens in a number of trials. The high protection obtained provided the basis for the State of Georgia to issue a license in 1970. Similar herpes viruses were isolated from turkeys in Australia, England, and in many countries on the continent.

The USDA took out a general patent and licensed many vaccine producers to make the turkey virus vaccine. It soon superseded the attenuated English vaccine and now is used by most poultrymen worldwide. Over 3 billion doses were produced in 1982 by U.S. manufacturers. Most of the vaccine is shipped to hatcheries in liquid nitrogen (at -273°C) and is administered to each baby chick by subcutaneous inoculation or during other procedures, e.g. "debeaking." The vaccine is also freeze-dried for shipment over long distances.

The economic benefits of the vaccine to the production of human food are remarkable. The benefit-cost ratio has been estimated at 44.3, which means that the average dollar spent on research will return $44.30 in economic benefits. In terms of reduced cost of production, it amounts to 5.6 cents per pound of broiler and 2.2 cents per dozen eggs. The use of the vaccine soon resulted in an overproduction of poultry meat and eggs, which in turn, resulted in a severe drop in prices. In 1972, exotic Newcastle disease appeared in California and required depopulation for eradication. The poultrymen quickly acquiesced! The supply and demand have since stabilized, and the benefits are now derived from decreased costs of production of broilers and eggs.

Human Significance —The virus of Marek's disease may have as its analog a possible causative agent of human cancer and may contribute to an understanding of human cancer. For example, Marek's disease was the first cancer shown to be caused by a herpes virus and the first neoplastic condition of any animal to be controlled by a commercially applicable vaccine. According to Dr. Frank L. Raucher, former Director of the National Cancer Institute, "These findings represent one of the single most important developments in cancer research within the past 10 years. They will contribute substantially not only to the control of this cancer in chickens but also to the prevention and control of cancers in man."

Brucellosis

Contagious abortion became a serious problem for the people of New England as early as 1843. Some herds had a few abortions year after year, but when brucellosis first appeared in a herd, almost every pregnant cow would abort within 1 or 2 years. In addition to loss of the calf, the cow gave little milk and sometimes was sterile. As soon as Dr. Bang, the Danish veterinarian, reported the isolation of a small organism, *Bacillus abortus* (later revised to *Bacterium abortum*, then to *Brucella abortus)*, from the placenta of aborting cows, the BAI attempted to confirm the finding; in 1900, pure cultures of an organism were obtained from an outbreak of abortion in the cows of a hospital in the District of Columbia. In 1911, BAI veterinarians reported that they recovered the organism from the milk of apparently healthy cows and from tonsils removed from children. Dr. Melvin, Chief of the BAI, recognized the threat to public health and work on the disease was expanded. In 1914, the organism was recovered from the liver and stomach of an aborted pig fetus during a storm of abortions in an Indiana swine herd.

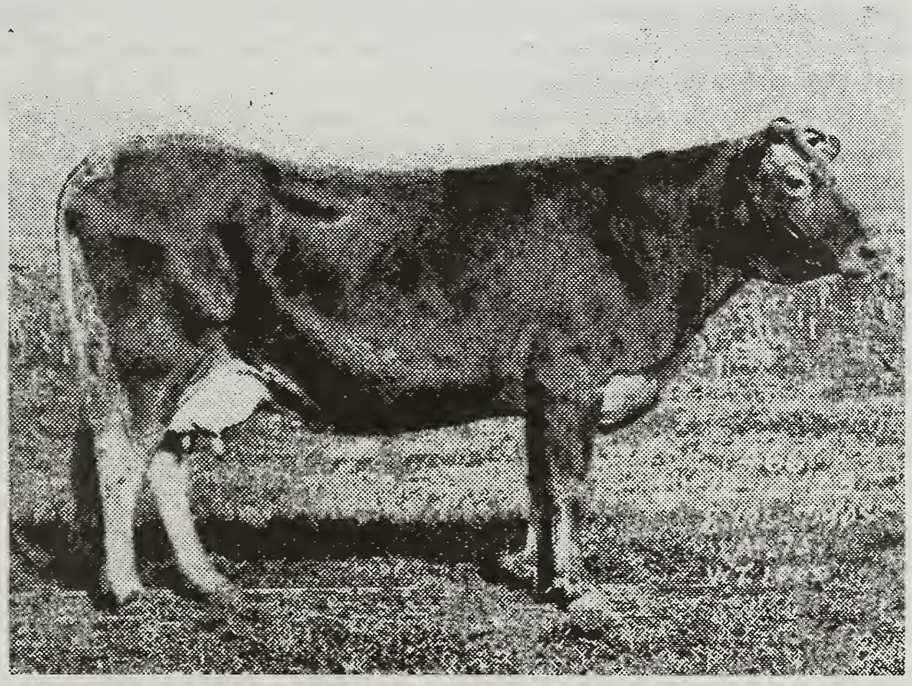
In 1915, Alice C. Evans joined the BAI and was assigned to studies on the bacteria in milk including the small organism from abortion herds. She knew that Indians on the reservations in the Southwest contracted a disease known as Malta fever by drinking milk from their apparently healthy goats, and that some goats shed in their milk a small organism called *Micrococcus melitensis*. The question arose naturally: Were the organisms from the milk of cows and goats the same? As recalled by Dr. Evans in 1947, "Immediately the bacteriologist set up simple experiments to test the idea, and with amazement noted that one result after another pointed to a close relationship between the strains of supposedly different genera." But if two organisms were closely related, why didn't the organism from cows cause human disease? The answer came in 1922 by way of infected swine. The organism of contagious abortion of cows was recovered from human patients in Baltimore, Sioux Falls, and elsewhere, who worked in slaughter houses and handled infected hogs or their carcasses. The BAI reports were quickly confirmed by workers in South Africa and elsewhere. In 1927, Evans described 20 cases of human brucellosis of bovine origin in a report in the *Journal of the American Medical Association*. Then the number of reported cases exploded; in 1938, over 4,000 cases were reported. Alice Evans resolved a third question: Since mild and unapparent infections are common in animals, why don't humans have chronic brucellosis? They do. She proved this during years of personal ill health, repeated medical examinations that failed to reveal the cause of complaint, and frustrating diagnoses of neurasthenia and/or malingering. Finally, during a surgical procedure for another problem, the surgeon found an abdominal lesion from which *Brucella melitensis* was cultivated; Dr. Evans was provided relief both from the infection and from the misunderstanding about chronic brucellosis. Most infections can be terminated by very large doses of antibacterial agents, but brucellosis is still occasionally misdiagnosed. For example, a USDA veterinarian working in a laboratory with brucella organisms became acutely ill with signs of meningitis. He was hospitalized and treated with antibiotics for several days. His fever subsided but mental aberrations persisted and he was placed in the psychiatry ward. He was removed the next day when the results of bacteriologic studies revealed brucellosis; he recovered with appropriate treatment.

In addition to *Brucella abortus* from cows and *Brucella melitensis* from goats (the generic name *Brucella* was derived from Bruce—the English physician who first isolated the organism from patients on the island of Malta), veterinarians in California isolated a third related organism from aborted swine fetuses; it was named *Brucella suis*. The diseases caused by all three organisms are called brucellosis.

Brucellosis Control—The BAI continued to develop information on brucellosis into the 1930's, with emphasis on the standardization of diagnostic antigens and on control by immunization. Progress was slow. As the disease continued to spread in beef and dairy herds throughout the country, entrepreneurs began to provide medicines for its treatment—mostly herb and iron tonics plus a potent dye (crystal violet, methylene blue), and many a cow barn burst into vivid green and blue colors after the cows were drenched with a favorite nostrum. In a fair percentage of cases, they seemed to work, because most cows aborted only once; if they became pregnant again, they usually delivered a live calf with or without methylene blue! Various vaccines were manufactured and sold. A "sero-vaccine" made in Philadelphia claimed to provide an "80 percent reduction in abortions in your cows." In 1928, 24 firms were licensed to make such products. Reports by the BAI that some products contained living organisms capable of causing persistent infections in cows stimulated the American Veterinary Medical Association and the United States Livestock Sanitary Association to action. In 1930, they asked for controls on virulent vaccines, for further standardization of the diagnostic agglutination test, and for more research. In 1933, the American Veterinary Medical Association recommended that field trials on vaccines be done under the supervision of the BAI. The first trial was made in 1936 using strain 19, a live culture of *Brucella abortus* of reduced virulence. Strain 19 was the 19th candidate culture of *Brucella abortus* isolated by Dr. John M. Buck, BAI veterinary bacteriologist, during his studies on immunization for the control of brucellosis. It was recovered from the milk of a Jersey cow in the BAI dairy herd (Fig. 2). The cow never aborted, but she became a

reactor to the agglutination test and became sterile. Dr. Buck isolated the organism in June 1923, determined that it was virulent, and then mislaid a slant culture under some papers on his desk for 2 years or more. Buck's research was not going well. Killed cultures of *Brucella abortus* did not protect animals against the disease and living cultures initiated infections. Perhaps a weakened (attenuated) culture would protect without causing disease? Perhaps the old cultures at room temperature had become weakened? So the rediscovered strain 19 was resurrected in the laboratory and inoculated into calves. It protected the calves from challenge with *Brucella abortus* but did not spread to other calves! Field trials were started in 1936 in Maryland, Ohio, Illinois, and Wisconsin with 260 herds containing over 19,000 cattle in which 15 percent or more were positive reactors to the agglutination test. All calves (14,000) between 5 and 7 months of age were given strain 19. The results were so good that vaccination of calves (and cows in special circumstances) was officially adopted for the control of brucellosis. In 1941, a BAI veterinarian hand-carried four cultures of strain 19 to England to help protect their cattle from the disease. It is now used worldwide to control bovine brucellosis. During many millions of vaccinations and subcultures, strain 19 has not reverted to its original virulence; a few cows, however, have had persistent infections, usually of the udder.

Fig. 2. Victor's Lady Matilda, the source of strain 19, an attenuated *Brucella abortus*. She was born in 1915 in Pennsylvania, joined the BAI herd in 1921, and established 2 records for the production of milk before she became infected.



Eradication Program—A cooperative State-Federal brucellosis eradication program was launched in 1934 as part of an emergency cattle reduction program because of severe drought conditions in some parts of the country. It provided for testing of herds, slaughter of the reactors, and for indemnity payments to the owners. By 1940, the first counties were declared free of brucellosis. To promote uniformity, all antigen for the agglutination test was made by the BAI and distributed free to States for the program. Progress slowed during the war, but in 1947 the program was given renewed emphasis with the adoption of the first uniform methods and rules, including both testing and vaccinating procedures. Under the National Brucellosis Committee (21 leading farm, livestock, and health groups were represented), the program has been broadened to include swine and goats, a market cattle testing procedure, and alternative tests (including the ring test and complement fixation). In 1955, the Secretary of Agriculture set a goal of 1975 as the target date for the eradication of brucellosis from the livestock of the United States.

This goal was not met, but much progress has been made. In 1934, the percent of reactors in all herds tested was 14 percent; it is now less than 1 percent. Economic costs have been reduced similarly. Cases of brucellosis in humans decreased from 6,400 in 1947 to 300 in 1975. Justification for the control and prevention of bovine brucellosis is both economic and public health. Brucellosis is a zoonosis—the incidence in human beings is directly related to the incidence in cattle, hogs, and goats.

Recent epidemiological studies have revealed the importance of extrinsic factors. The trend toward larger herds, for example, results in greater likelihood of infection and greater difficulty in eliminating the disease. Climate, topography, and even the price of fluid milk versus butter and cheese are factors in the eradication of brucellosis. The intricate relationships of *Brucella abortus* and cattle give rise to variable incubation periods, latent infection, and even seronegative cows that abort. In addition to the intrinsic and extrinsic factors of the host-parasite relationships, logistical and techni-

cal limitations of the program have engendered a relationship of confrontation and antagonism between some cattlemen and governmental agencies which, we fear, assures the existence of bovine brucellosis for many decades.

Glanders

A bacterium that produces fatal infections in cats, humans, and horses is quite unique. *Pseudomonas mallei* (formerly identified as *Bacillus mallei*) is such a microorganism. Glanders has had particular attention because of its drastic effect on horses associated with the movements of armies. It received the Greek name of malleus from Aristotle (400 B.C.) and was recognized as contagious as early as the 4th century. Control measures were devised that were somewhat effective except during the times of war. Glanders is believed to have entered the United States at the end of the 18th century. With the westward movement of the population, the disease moved similarly. There were several severe outbreaks among horses and mules of the U.S. army.

Glanders is transmitted between animals by discharges from the lungs, nose, or skin, and by contaminated mangers, utensils, bedding, etc. Man may become infected either directly or indirectly by contact with diseased animals. Deaths among humans have been most common in laboratory workers, army veterinarians, and at veterninary schools; BAI employees, however, avoided the infection.

Attempts to induce immunity to the organism were not successful. As a consequence, control was directed to the identification of infected animals by clinical signs and later by serologic tests. In addition, infected animals can be detected by the use of a sterile extract of *Pseudomas mallei* called mallein. Mallein is given by subcutaneous or intracutaneous inoculation or dropped into the eye. A positive reaction is evidenced by swelling, hyperemia, and purulent discharge at the site of inoculation. Infected animals are quarantined until they are destroyed. Countries with reasonably effective veterinary services have been able to eliminate glanders through the persistent use of testing procedures both on their own horses and on those that are being considered for importation. The U.S. cleared the final vestiges of glanders during the 1940s.

Dourine

The trypanosome producing dourine of horses is transmitted only by contact at the time of copulation. It was probably introduced into the U.S. from France with the introduction of a Percheron stallion to Illinois in 1882. But the disease was not identified until 1886 and consequently it spread throughout the Midwest and the Southwest.

It was not until 1912 that a complement fixation test was developed to identify antibodies in infected horses. Because of the diversity of patterns of agriculture in the West and Southwest, control of breeding animals could not be used as a way to eliminate dourine from horses. But with the discovery of a serological test, it became possible to identify infected animals; then the BAI developed a test and slaughter program incorporating payment of indemnities to owners. Payment usually involved both State and Federal governments except on Indian reservations where the entire expense was borne by the Federal Government. As is the case with glanders, countries with effective veterinary services have eliminated dourine. This was accomplished in the U.S. during the 1940s.

Cattle Tick Fever

In reviewing the fascinating saga of Texas fever, it must be remembered that this was the first disease to be identified in which a protozoal parasite was communicated to a mammalian species through an arthropod vector. The idea that disease could be transmitted by ticks was generally discredited by the scientific community at the time. The disease was variously known as distemper of cattle, murrain, cattle fever, and of course to the dismay of Texans, Texas fever. It may have been introduced into north America during the Spanish colonization of the West Indies and Mexico. The first recorded reference to the disease in the colonies was in 1744 when the Governor of South Carolina issued a quarantine against distemper of cattle because of high mortality between 1741 and 1744. Subsequently, States to the North legislated numerous restrictions on the movement of cattle from the Carolinas and Georgia.

In 1796, the disease was reported in Lancaster County, PA, involving cattle previously brought in from South Carolina. If southern cattle mingled with northern cattle, the northern cattle contracted the disease. In one instance, it was caused by merely placing northern cattle on ground where southern cattle had previously been penned. It was also noted that outbreaks of the strange disease were limited to the summer time and that they disappeared with the first heavy frost. And to compound the confusion, it was repeatedly observed that even though southern cattle appeared to be

responsible for spreading the infection, they seemed to be perfectly healthy.

By the middle of the 19th century, similar experiences were described in the West and Southwest. After the Civil War when Texas cattle producers began to move their animals to slaughter in the North, severe reactions took place involving not only the cattle population but the related humans as well. In 1866, Missouri farmers established a "shotgun quarantine" against passage of trail herds from Texas. Also that same year, citizens of Kansas turned back a Texas herd by killing 40 cattle. In order to avoid hostile opposition associated with overland trailing, Texas cattlemen moved their cattle by boat to Illinois; approximately 20,000 cattle were shipped to Cairo and Texas fever spread through Illinois and as far east as Massachusetts.

As early as 1868, Professor R. C. Styles of Brooklyn, NY, reported small bodies in the erythrocytes of sick cattle. The observation was not repeated and it was forgotten until the BAI report of Smith and Kilborne in 1889. In 1883, USDA began work on the Atlantic coast to establish the northern extent of cattle fever and thus inaugurate the well-known "Texas fever line." A few years later, it was shown that the line coincided with the northern limit of the tick vector. The line was gradually extended across the country a little north of the 35th parallel. On July 3, 1889, the first national quarantine order was issued to control the movement of southern cattle. This quarantine and the strict enforcement of regulations to permit the shipment of southern cattle to northern markets for immediate slaughter were effective only in checking the spread of the disease but did little to improve conditions in the quarantined area.

In 1890, the BAI established that ticks were necessary for the transmission of the disease. This was the first conclusive evidence that an infectious disease could be transmitted by an intermediate host from one animal to another. Further research revealed the life cycle of the tick, and that ticks could be destroyed by dipping the host animals in arsenical solutions, thereby preventing the infestation of pastures. When the BAI determined that the disease was most effectively handled by elimination of the tick, control efforts began officially in 1906. Cattle could be moved from the quarantine area, that area south of the Texas fever line, to areas outside the quarantine area only if accompanied by a special permit. Specific areas south of the Texas fever line would be cleared of ticks and released from quarantine if the effort was supported by popular demand and if adequate dipping and animal control procedures were followed.

As with any effort to control movement, regardless of the ultimate objective, violations of the regulations in maintaining the quarantine line were common. The more progressive cattle owners showed considerable enthusiasm for tick eradication, but many persons considered tick eradication an impossible objective. Since the major objective was eradication of ticks, it was necessary to apply acaricides to cattle at regular intervals. Dipping vats were constructed and maintained by community labor. All cattle in an area around each vat were to be dipped by a specific date. For a time, opposition to dipping cattle and to the regulations was clearly evident—some vats were blown up by dynamite! And four BAI control officers were killed by farmers who opposed the program!

It is obvious that tick inspectors assigned to tick identification and quarantine activities had to be compatible with their surroundings. For example, inspectors in the Southwest had to be competent cowboys with the ability to use a lariat and also had to have the technical qualifications necessary for the job. One professor in a veterinary school took great relish in recounting his experiences as a tick inspector with the program in Texas. He and a group of cowboys were bivouaced overnight when they were joined by a band of unsavory characters, one of whom was Gomez, a fugitive from justice. Suddenly the professor stuck his finger in the back of the fugitive with, "Drop that gun, Gomez, this is Inspector Caster of the BAI," whereupon the objective of justice surrendered. Presumably Gomez suffered the consequences of whatever his crime might have been.

By 1943, the cattle fever tick, *Boophilus*, was eradicated from the continental United States except for a narrow buffer zone which was maintained under Federal and State quarantine along the Texas-Mexican border. Deaths of cattle from tick fever stopped, and southern cattle moved to markets without restrictions for tick fever. The cash expenditures by Federal, State, and county governments for eliminating this parasite were approximately half the losses by the southern cattle industry in a single year before eradication work was started.

The courage and vigor demonstrated by the new BAI in undertaking such a vast responsibility with so many unknowns resulted in several medical milestones. Establishment of the "Texas fever line" was an early application of the geographical approach to medical research; it became a principle of disease control by the BAI. Texas fever was the first example of a mammalian disease capable of being transmitted by an arthropod vector. Following this achievement, other medical research revealed other diseases with similar transmission patterns; e.g., yellow fever, malaria, typhus, and Rocky

Mountain spotted fever. Texas fever was the first disease to be eradicated by elimination of the vector; and it was the first major disease to be eradicated by the use of chemical agents directed at the vector. The Texas fever operation of the BAI was a huge commitment of technical and human resources, but with minimal fiscal support. Its success over a sustained period of time was accomplished by a viable livestock industry supporting competent scientists all working toward a common goal. Undoubtedly, it was one of the more significant achievements of the BAI. Slow virus diseases have incubation periods of months to years and a progressive course that leads to death. USDA scientists are studying scrapie, progressive pneumonia of sheep, and a newly discovered virus that causes arthritis and encephalometis in goats. At the Animal Disease Research Unit, Pullman, WA, they are investigating an economically important slow-virus disease of mink called Aleutian disease. Although all color phases of mink are affected, Aleutian mink are much more susceptible. The disease now is recognized by mink ranchers throughout the world. Death is caused by immune complexes of virus particles and antibodies which obstruct the glomeruli (filter apparatus) of the kidney and the mink succumb to uremia. The virus (parvovirus) can be transmitted from the affected dam to her unborn kittens or between different families by feces, urine or saliva. Vaccines for the prevention of Aleutian disease are not yet available. The disease, therefore, is controlled on mink farms by testing to detect carrier animals, which are removed from the farm.

MODERN VETERINARY MEDICINE IN USDA

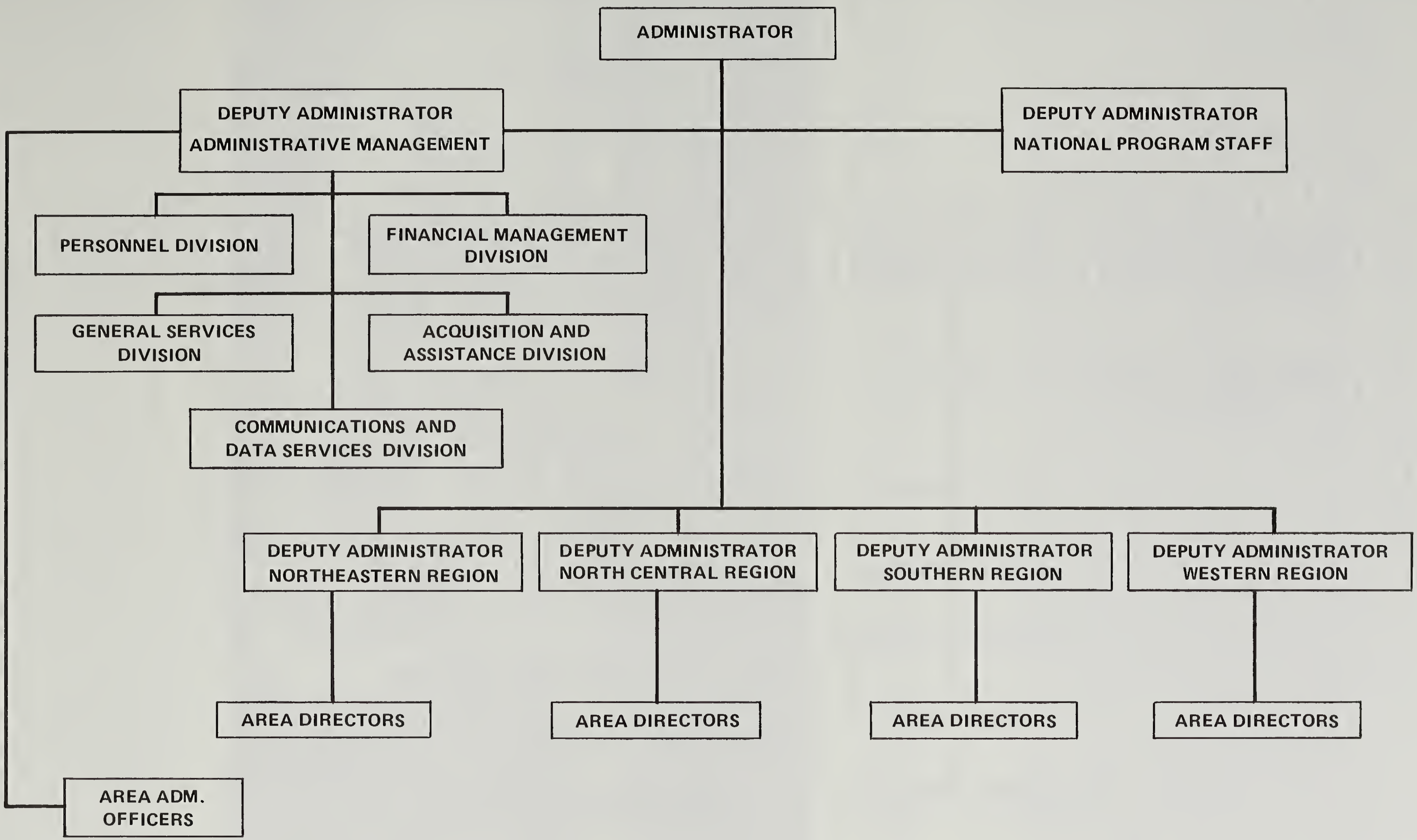
When the Eisenhower Administration came into office in January 1953, there was quite a stir of activity aimed at "economizing, streamlining, and simplifying" the management of USDA activities. One result of the deliberations was the termination of several Bureaus under the coordinating authority of the Administrator of the Agricultural Research Administration, and the realignment of their activities under the direct authority of the Administrator of the Agricultural Research Service (ARS). This occurred in January 1954. As recommended by the Hoover Commission, the activities of the BAI were separated into three categories; i.e., Research, Meat Inspection, and Animal Disease Prevention and Control. That was the last of the BAI as a separate organization, but all of its activities continued within several divisions of ARS (see Fig. 3 for an organizational chart). The way these agencies cooperate in efforts to promote the mutual goal—animal health, can be illustrated by a few examples. If the meat inspectors find animals with tuberculosis, they notify the field force; the animals are "traced back" to the farm of origin; the herd is tested, and all necessary measures are taken to eliminate the disease. To assist the field force, ARS scientists develop special diagnostic tests and reagents, and, for example, determine the amount of cooking needed to inactivate tubercle bacilli in pork. Exotic diseases are studied at ARS laboratories to provide the regulatory force with information so that they will be able to detect and control foreign animal diseases should they be introduced into our herds or flocks. Following the reorganization of the BAI in 1953, the activities of the various divisions were coordinated by Dr. M. R. Clarkson. In this role, he was the chief representative of the veterinary profession in the Department of Agriculture until his retirement in 1964.

New Areas

Veterinary research organizations of USDA now are moving into newer kinds of research where sophisticated techniques are used to study the mechanisms of disease on a molecular level. Data accumulate so quickly that a team of investigators, sometimes aided by a computer, is needed to collate it into usable form. Most diseases caused by single or sole agents are pretty well understood; attention is now turning to diseases of multiple causation and those that result from such factors as immune deficiencies.

The Agricultural Research Service and the Cooperative State Research Service of USDA administer veterinary research at several "centers," channel money to State institutions, and make grants for specific projects in this country and several foreign countries using Congressional appropriations and "formula" grants like the Hatch fund. The major research facilities (now often referred to as Centers) were established by Congress for specific purposes in the national interests, usually in response to official statements by livestock owner organizations (The National Cattlemen's Association, The United States Animal Health Association, The National Pork Producers' Council, etc.) or to persuasive reports by Congressional committees. For example, the Senate Select Committee on Veterinary Medicine (the so-called Humphrey Report), surveyed the national veterinary research facilities and concluded a new laboratory was urgently needed and eminently justified, thus prompting congressional authorization for the National Animal Disease Center to replace and enlarge facilities at Beltsville, MD.

AGRICULTURAL RESEARCH SERVICE ORGANIZATION



VETERINARY SERVICES ORGANIZATION

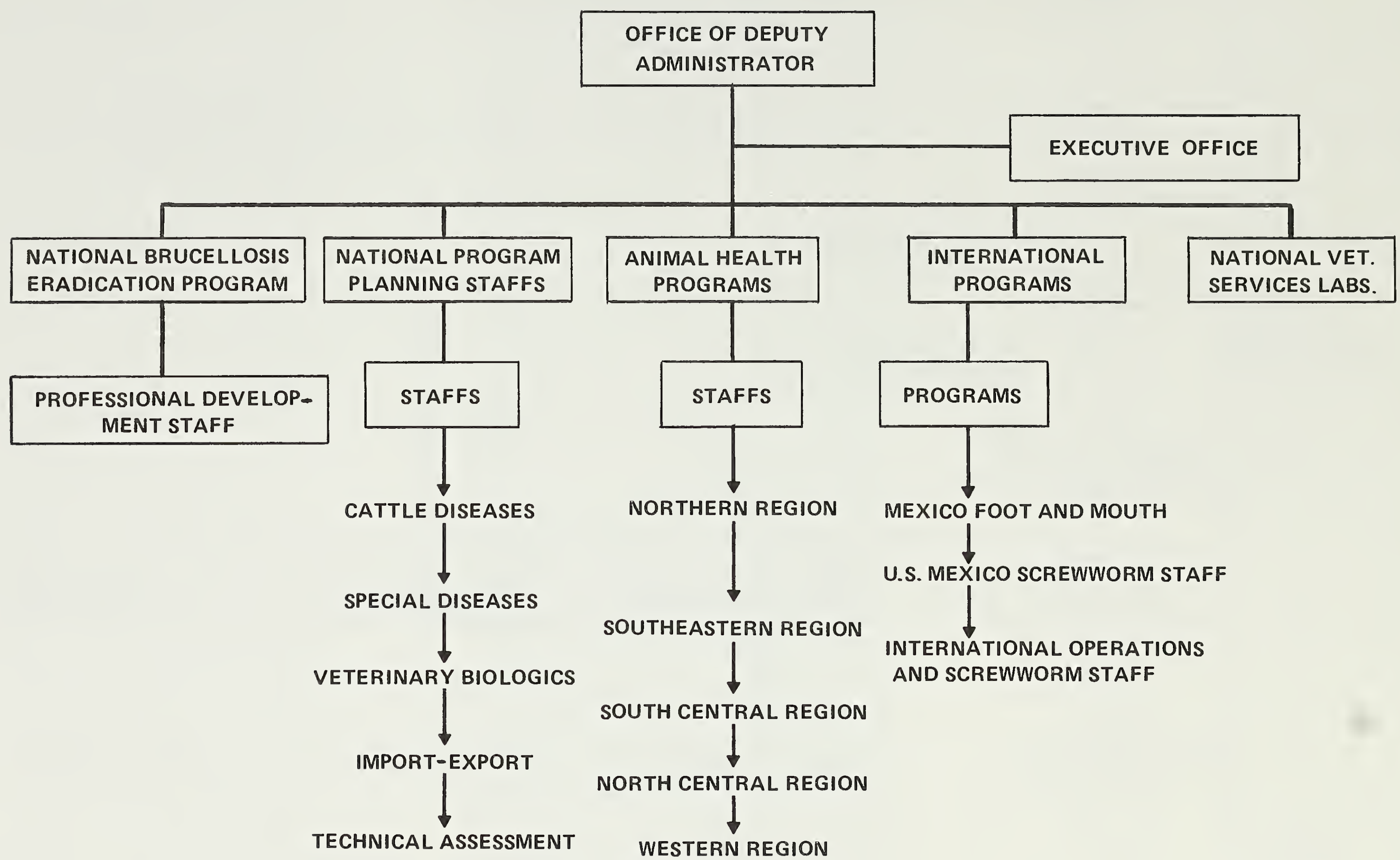


Figure 3.

The National Animal Disease Center

The Center was established by USDA on July 27, 1956, when President Eisenhower signed the appropriation bill containing $16 million to construct a new laboratory at Ames, Iowa. It was dedicated on December 14, 1961, when the grounds were closed to the public and research began. The mission of the Center was, and continues to be, to conduct basic and applied research on the diseases of livestock of major economic importance to the Nation's agriculture. The staff is committed to excellence in veterinary research and to an interdisciplinary approach to finding solutions to animal health problems. Approximately 30 diseases of cattle, swine, poultry, sheep, horses, and other animals are being studied by over 60 scientists, about half of whom are veterinarians. Although some persistent problems like tuberculosis are still being studied, most of the work is now done on infections that have assumed greater importance as a result of changes in animal husbandry, "emerging" diseases of uncertain importance and/or etiology, diseases of multiple causation (usually called syndromes), or on mechanisms of a disease, with a view to inhibiting or blocking the means by which the pathologic agent initiates the disease process. Noninfectious conditions are also studied. For example, efforts to understand the mechanism of milk fever, a common but mysterious paralysis of dairy cows at calving time, have led scientists into sophisticated experiments on the role of vitamin D and hormones in mineral metabolism, which recently provided clues to better management of the dairy cow and incidentally, of diabetes in human patients.

The Plum Island Animal Disease Center

The Center was established in 1953 as a research facility devoted to preventing foreign diseases of animals from endangering the livestock population of the United States. It is located on an island east of Long Island, NY, a site chosen to minimize the possible escape of foreign animal disease agents to the U.S. mainland.

The Plum Island Animal Disease Center, Long Island, NY.

Threats of outbreaks of foreign animal diseases in the United States, with potential risks that they might become established in the country, have increased in recent years as man and animals continue to move across international borders in ever-increasing numbers. Modern rapid transportation has increased the potential for the spread of diseases among countries. The livestock population of the United States is susceptible to foreign diseases, such as foot-and-mouth disease and African swine fever, and foreign diseases must be guarded against with every available means. Efforts of the Center are directed to keeping our livestock safe from the economic catastrophe that would result should an outbreak occur. Thus, the Plum Island Animal Disease Center is responsible for developing diagnostic capabilities

for animal diseases that are foreign to the United States, conducting a wide range of research endeavors on the causative agents of these diseases, and developing procedures for the safe importation of animals and animal products. Recently, responsibility for the diagnostic services at the Center were transferred from ARS to the Animal and Plant Health Inspection Service of USDA.

A major contribution from the Center was the development of a cloned viral protein that is the basis for a vaccine for foot-and-mouth disease. Plum Island scientists demonstrated that the coat protein from the virus could be used to vaccinate livestock, identified the amino acids specifying this protein, and with scientists at Genentech, Inc., transferred the appropriate gene from type A foot-and-mouth disease virus to a harmless strain of *Escherichia coli*, causing it to produce protein that was as immunogenic in livestock as protein isolated from virus particles. Adaptation of this technology to commercial production of vaccines is in progress.

The Arthropod-borne Animal Disease Research Laboratory

The Laboratory was established in 1940 as a diagnostic facility of the BAI in Denver, CO. Research is conducted on viral diseases transmitted to animals by insects—mosquitoes, flies, and ticks. These diseases include the encephalitides and a particularly intractable disease of sheep—bluetongue. Bluetongue, however, also was detected in cattle in 1952 and is considered a major animal health problem.

The Livestock Insects Laboratory

The Laboratory, now at Kerrville, TX, was established by the BAI in the 1930's at Albuquerque, NM, to conduct research on scabies (mange) in cattle and sheep—serious problems for livestock men of the West. The program was transferred to Kerrville in 1976. The Laboratory has been the main source for information on ways to control mange mites in both cattle and sheep. Scabies was one of the diseases that led to the establishment of the BAI. The disease has been eradicated from sheep but research has still not found a satisfactory way to eliminate the lowly but persistent mange mite from cattle.

The Poisonous Plant Research Laboratory

The installation at Logan, UT, was established to study poisonous plants and develop methods to prevent or moderate livestock poisoning due to these plants. At the present time, scientists are studying the chemistry of the toxic compounds in locoweed and *Astragalus* plants and their effects in livestock, and seeking ways to control poisonous range weeds by chemical, biological, cultural, physical, and integrated methods that are safe and without hazards to the environment. The flora of the West includes many poisonous plants that were not known to the BAI veterinarians or to the early livestock men. Even the U.S. Army lost horses. For example, some historians maintain that General Custer's horses were "locoed" from grazing on locoweed in the spring of 1876 as the army advanced into the Little Bighorn mountains, and that their poor performance was a major factor in Custer's defeat.

The inception of chemistry as a science in the United States can be traced to the arrival here of Joseph Priestly in 1794. The administration of President Jefferson actively promoted the young science and introduced the experimental approach in agriculture. Questions about plant poisoning of livestock subsequently came to USDA with increasing frequency. In 1884, a cattle disease, characterized by sloughing of the hoofs and other signs, was reported from Kansas. A local veterinarian diagnosed it as foot-and-mouth disease—a serious problem in the Northeast at the time. The imminence in Kansas of a quarantine on cattle, at that time the primary resource of the State, caused great public excitement. Several veterinarians were detailed by the Army Veterinary Service, by various State governments, and by the Canadian government to investigate the situation, and conflicting reports soon appeared. The BAI, which had just been organized, sent M.R. Trumblower to make an investigation; D. E. Salmon also investigated. The correct diagnosis of noninfectious ergotism made by Salmon and several others eventually prevailed, but the incident served dramatically to emphasize the problems that poisonous plants could raise. The disastrous "horse plague" of 1912 was suspected to be a poisoning of plant origin and the mycologist Charles Thom and BAI veterinarians were sent to Kansas to make investigations, but no conclusions were reached. The horse plague now is regarded as an epizootic of encephalitis. Since then, the BAI and, later, the ARS have continued to study poisonous plants—ergotism and several other diseases of suspected fungal etiology (reflecting the contemporary interest in microorganisms and the higher fungi), loco poisoning (certain species of *Astragalus* and *Oxytropis*), crotalism or "bottom disease" (*Crotalaria spp.*), larkspur (*Delphinium spp.*), water hemlock, lupines, castor bean, and others. Experimental work by USDA veterinarians on poisonous plants was done at several laboratories, all in the western States, until 1955 when activities were moved

to the Laboratory at Logan with field investigations throughout the West.

In the 1950's, some plants were shown to be teratogenic; i.e., after the dams grazed on certain plants, they gave birth to lambs or calves with congenital defects. For example, USDA scientists at the Logan Laboratory showed that *Veratrum californium* caused cyclopian and other malformations of the head in lambs born to ewes that ingested the plant on the 14th day of gestation. The deformities varied from a single median eye (cyclops), to shortening of the upper jaw, to milder defects. Laboratory chemists have isolated and purified the active teratogenic compounds.

The Veterinary Toxicology and Entomology Research Laboratory

This Laboratory was authorized by Congress in 1964 and dedicated on April 1, 1971. It is located at College Station, TX, on a 55-acre site donated to USDA by Texas A&M University. Approximately 40 scientists and support staff perform research to protect livestock from toxic agents and insect pests. The toxicological research concerns natural toxicants from plants and the toxic effects of agricultural chemicals. The entomological research concerns the hormones which regulate the physiological functions of insects.

In addition to the main Centers and laboratories, USDA supported veterinary research in 1982 at the Regional Poultry Research Laboratory, East Lansing, MI; Southeast Poultry Research Laboratory, Athens, GA; Animal Disease Research Unit, Pullman, WA; and at several smaller stations located in the United States and overseas as follows:

USDA Veterinary Research Locations

Auburn, AL
Davis, CA
Fort Collins, CO
Gainesville, FL
Athens, GA
Tifton, GA
Moscow, ID
Lafayette, IN
Ames, IA
Baton Rouge, LA
Lake Charles, LA
Beltsville, MD
Amherst, MA
Mississippi State, MS
Columbia, MO
Bozeman, MT
Lincoln, NE
North Platte, NE
Las Cruces, NM
Hempstead, NY
Ithaca, NY
Fargo, ND
El Reno, OK
Hugo, OK
Poteau, OK
Stillwater, OK,
University Park, PA
Vermillion, SD
Knoxville, TN
Memphis, TN
Austin, TX
Bushland, TX
College Station, TX
Falcon Heights, TX
Kerrville, TX
Mission, TX
Burlington, VT
Blacksburg, VA
Pullman, WA
Madison, WI
Dokki, Egypt
Cairo, Egypt
Hissar, India
Muguga, Kenya
Tuxtla Gutierrez, Mexico
Karachi, Pakistan
Quetta, Pakistan
Mayaguez, Puerto Rico
Novi Sad, Yugoslavia

USDA VETERINARY RESEARCH CONTRIBUTIONS

Veterinary Extension Service

In 1914, Congress established a nationwide, extension/educational system funded and guided by a partnership of Federal, State and local governments to deliver information to help people help themselves through the land-grant university system. Books, bulletins, reports, and other written materials by BAI veterinarians became part of the education effort of the Extension Service.

Early in the 20th century, transportation was slow; and without adequate telephone service, communication was difficult. Veterinary practice was relatively primitive. Even with the availability of the automobile, roads were often impassable due to mud or snow, and consequently the veterinarian was often inaccessible. Under these circumstances, it is not surprising that some early Extension Service workers undertook to train farmers to do their own veterinary work. Shortly after the advent of hog cholera serum and virus, the Extension Service was required by law to conduct vaccination schools to instruct swine producers on how to vaccinate their own pigs. This was the result of legislation sought by the swine industry because they thought some veterinarians were making exorbitant charges for hog cholera vaccination. This left ill feeling among some veterinary practitioners toward the Extension Service that was to last for several years.

The entry of extension veterinarians into the Extension Service is a recent development: Dr. J. B. Cline began Extension duties at Iowa State College in 1912 and California, Minnesota, and Indiana soon had veterinarians with extension responsibilities. By 1941, there were 11 full-time extension veterinarians and others part-time. Today, there are about 125 full- or part-time extension veterinarians in the United States. They interpret, disseminate, and encourage practical use of the best information in veterinary medicine, and of the latest results of USDA veterinary research to prevent, control, and eradicate diseases and parasites of animals.

Veterinary Research

As the veterinary profession matured (particularly since World War II), it maintained its ties to agriculture while adopting many of the techniques of biomedical science. Consequently, animals can now receive the benefits of the most advanced medical methods (laser surgery, organ transplants, etc.), and veterinarians do blood analyses, embryo transplants and computer aided diagnoses on farms and ranches with disease problems. At the same time, veterinary research evolved so that in many areas it is in the leading edge of science and technology.

Even the style of management changed. The old methods of the BAI, with clear cut assignments, a high degree of specialization, a hierarchy of command, and a reliance on rules, gave way, at some laboratories, to the systems approach, where groups of scientists are in moving equilibrium with each other and several external systems, such as colleagues, other research organization, and the public. Because an individual may move freely to his or her level of competency, creativity and productivity are often enhanced. But the manager of a systems organization often lacks full control of a situation and must learn to shape actions and guide the direction of research toward the goal. The systems style seems to have caught on at some USDA veterinary laboratories. Researchers have moved ahead into molecular biology—monoclonal antibodies, for example, and gene splicing and the first subunit vaccines. At the National Animal Disease Center, a weekly seminar with the distinctive title, "The Gut," attracts the enthusiastic participation of veterinarians, bacteriologists, virologists, geneticists, electron microscopists and others, all contributing their information toward solving problems of enteric diseases. Such sophisticated research often requires complicated and costly equipment; in the systems style of management, to be used by anyone who needs to use it.

But centralized management has also evolved. For the first time, USDA veterinary research has been integrated into the overall plans for improved production of animals for food. Under a 6-year blueprint, ARS will channel greater funding into basic, rather than applied research with emphasis on the isolation and identification of organisms inhibiting animal production and on identifying the proteins of viruses. The goal is a 50/50 ratio of applied to basic research rather than the present ratio of 60/40. The ultimate goal is to give the animal health industry new technologies for the control and eradication of animal diseases.

Veterinary Services

Regulatory programs for the control of animal diseases are now the responsibility of Veterinary Services (VS), a unit of the Animal and Plant Health Inspection Service (APHIS). VS is a team of veterinarians, other professionals, animal health technicians, and support personnel with six primary tasks: keeping foreign animal diseases out of the country, eradicating outbreaks that get past our border defenses, eradicating domestic diseases of economic and/or human health significance, preventing the interstate spread of animal diseases, assuring safe and potent veterinary biologics, and assuring the humane care of animals. Disease control and eradication programs are carried out through close cooperation with State governments, the veterinary profession, and the livestock and poultry industries.

Livestock, poultry, and pets are continually threatened by diseases with effects ranging from slight debilitation and economic loss to decimation of flocks and herds. Several of these diseases also affect man. The best economic approach

to livestock and poultry diseases is to eradicate them wherever feasible. Preventing the introduction of foreign animal diseases and eradicating those domestic diseases that are of major economic significance eliminates the need for continuous control programs and the annual costs associated with them. The policy of animal disease eradication—rather than control—became firmly established in the early years of the BAI. The basic procedures of quarantine, slaughter, and disinfection proved again and again that animal diseases could be eradicated. The principle of cooperation with the States in disease eradication programs also became established in the early years. Diseases eradicated from the United States include the following:

Year	*Disease*
1892	Contagious bovine pleuropneumonia
1929	Foot-and-mouth disease
1929	Fowl plague
1934	Glanders
1942	Dourine
1943	Cattle fever ticks
1959	Vesicular exanthema
1959 & 66	Screwworms (southeast & southwest)
1971	Venezuelan equine encephalitis
1973	Sheep scabies
1974	Exotic Newcastle disease
1978	Hog cholera

Organization—The VS deputy administrator, headquartered in Washington, D.C., participates with the APHIS administrator and other USDA officials in developing and carrying out programs under the six areas listed above. The deputy administrator and his associate direct all VS activities, which are carried out by about 2,400 permanent employees including about 640 veterinarians. The deputy administrator of VS has two assistants. One assistant, in charge of international operations, is responsible for cooperative surveillance programs for foot-and-mouth disease with Mexico, Central America, Panama, and South America; the U.S.-Mexico screwworm eradication program; and a disease intelligence service for Europe, the Middle East, and Africa. The other assistant deputy administrator is responsible for domestic animal health and animal care programs. Five regional directors (who report to the assistant deputy administrator responsible for animal health and animal care programs) are responsible for planning, directing and coordinating activities in their assigned groups of States. They are headquartered at Scotia, NY, Tampa, FL, Ft. Worth, TX, Denver, CO, and Reno, NV. Reporting to each regional director are veterinarians in charge (AVIC's), along with regional veterinary epidemiologists, compliance officers, biologics specialists, and animal care specialists who are responsible for field activities in a State.

Administrative Programs—The administrators of VS at Hyattsville, MD, provide leadership for on-going VS programs. Staffs formulate standards, regulations, and model laws; develop methods and procedures; develop budgets; and provide scientific and technical support for funded VS programs. They are also required to keep up to date on diseases in their program areas. The following units report to the director of VS:

The cattle diseases staff provides support for cattle tuberculosis and maintains an interest in and knowledge of anaplasmosis, anthrax, bovine leukosis, cysticercosis, mastitis, and other diseases of cattle. The brucellosis section provides support for both cattle and swine brucellosis for the director of the national brucellosis eradication program.

Import-export develops policy to prevent the entry of diseased animals, birds, or animal products and policy to prevent the export of unhealthy livestock and poultry. The staff issues import and movement permits for animals and birds and import and movement permits for organisms and vectors. Certificates of pure breeding are also checked to see if they qualify for duty-free entry as purebred livestock if they are of a breed listed in the Code of Federal Regulations.

Interstate inspection and compliance handles animal identification programs and processes enforcement activities under animal care, animal quarantine, and veterinary biologics regulations. The staff also processes veterinary accreditation violations, market standards, and cooperative agreements with persons, States, or other agencies.

Special Diseases has programs for cattle fever ticks, cattle scabies, pseudorabies, and scrapie. Diseases that are not funded but are monitored include bluetongue, Venezuelan equine encephalitis, contagious equine infectious ane-

mia, equine piroplasmosis, exotic Newcastle disease, ornithosis, and salmonellosis. In addition, Special Diseases administers the National Poultry Improvement Plan, the Swine Health Protection Act, develops technical data on dipping and spraying facilities, and evaluates and recommends pesticides for listing as USDA-permitted pesticides.

Technical Assessment studies current VS programs to see that the technical abilities and methods in use are still effective in carrying out the mission, and looks at the potential of new techniques and diagnostic tools as they relate to regulatory veterinary medicine.

Veterinary Biologics develops regulations to implement the Virus-Serum-Toxin Act of 1913, which requires that vaccines, bacterins, antitoxins and similar veterinary biologics be safe, pure, potent, and effective before they are shipped across State lines.

Professional Development plans and carries out training programs, maintains liaison with veterinary institutions, provides training for foreign visitors, and administers the veterinary accreditation program.

Information Support for all VS activities and programs is provided through the veterinary services programs branch of the APHIS Information Division.

Regulatory Programs

Animal Welfare—In 1966, legislation was enacted to regulate trade in dogs and cats used for laboratory research; it was aimed at stopping "petnapping." Amendments in 1970 and 1976 greatly broadened the scope of the Animal Welfare Act. Industries subject to the act, in addition to research facilities, include zoos, circuses, roadside parks exhibiting animals, wholesale dog breeders and brokers, retail pet stores selling exotic animals, and common carriers and intermediate handlers transporting live animals. Not included under the act are farm animals and all cold-blooded animals, such as reptiles and fish. In addition, laboratory rats and mice are exempt under regulation. Minimum standards have been established for the care and treatment of animals covered by the act. Five standards deal with adequate facilities: housing, protection from bad weather, separation of incompatible animals, sanitation, and ventilation. The remaining five cover other aspects of humane treatment: feeding, watering, veterinary care, handling, and transportation. APHIS enforces the act through a system of licensing and registration and by inspecting those covered by the act to make sure they are in compliance with the standards. Violators are prosecuted through administrative and criminal proceedings.

Horse Protection—The Horse Protection Act, passed in 1970 and amended in 1976, is aimed at stopping the practice of soring horses. Soring is the use of cruel methods, devices, or irritants to cause pain in a horse's legs. It is done to accentuate a horse's gait in the show ring and thus gain unfair advantage over horses that are not sore. Because the Tennessee Walking Horse industry commonly used this practice to accentuate show ring gaits, VS regulatory activities have centered upon those shows and sales.

A sored horse changes its gait by placing its hind feet further forward to relieve the pain in the front feet and by raising the front feet quickly whenever they strike the ground. The resulting high-stepping, far-reaching motion is known in horse circles as the "big lick." VS has initiated rules giving the walking horse industry the opportunity for self regulation through the use of "designated qualified persons," who, when trained and licensed, can be used by management to exclude sored horses from the show ring and thus relieve management of its liability under the act. Shows continue to be monitored by VS personnel, however, through inspections and the use of thermovision. The latter technique scans a horse's legs with infrared sensors that detect temperature changes.

Since inflammation caused by soring results in a heat rise in the sored area, the "heat image" from the thermovision produces useful information that can be photographed and used as evidence of soring. Violators of the act are prosecuted in Federal courts or through USDA administrative procedures.

Identification—Identification is a key part of most animal disease control and eradication programs. A number of devices and methods—including plastic and metal eartags, hot iron and freeze brands, backtags, and tattoos—are used to identify livestock in trade channels so they can be traced to the farm or ranch of origin. Uniform coded eartags and backtags are supplied by VS and constitute the principal identification devices used in our national programs. Similarly, swine identification uses eartags, backtags, and tattoos. These systems make it possible to screen livestock at concentration points and slaughter plants for brucellosis and tuberculosis and to trace back to the foci of infection.

Export—To assure that the United States exports only healthy poultry and livestock—and thus maintains its good reputation—VS requires that animals be examined and certified free of communicable diseases before they are shipped to foreign nations. Examinations and tests—usually done by accredited veterinarians—cover both the U.S. export health requirements and the frequently complex import requirements of the receiving nation. After all tests and other requirements have been met, a VS veterinarian endorses the export health certificates. Then a final examination is conducted at the port of export by a VS veterinarian before the livestock or poultry leave the country.

Import—Our first line of defense against foreign animal diseases is strict control of the importation of animals and products that could spread disease. Therefore, VS continually reviews information of the processing of animal products, new tests for diseases, new precautionary treatments of animals and birds, and disease trends in foreign countries. On the basis of this information, appropriate changes are made in our import regulations and inspection procedures.

Control also is maintained over the importation and domestic movement of infectious organisms and their vectors to make sure that such movements do not constitute a threat to our livestock industry. Research on animal diseases is done in many laboratories in the United States, and scientists often want to import organisms from foreign countries or obtain them from other U.S. laboratories. All such imports—and many of the interstate movements—must be accompanied by a VS permit.

Permits are issued by the import-export staff for the importation of animals through animal import centers at Miami, FL, and Honolulu, HI, and a larger center at Newburgh, NY. Approximately 800 horses, 300 zoo animals, 1,800 cattle, and 4,000 poultry are imported annually through the New York Animal Import Center. Birds are imported through any animal import center or through privately owned quarantine stations approved to operate under VS supervision. In 1982, there were about 90 privately owned quarantine stations for birds throughout the United States.

An offshore maximum-security center—the Harry S. Truman Animal Import Center at Fleming Key, FL—provides quarantine services for cattle imported directly from countries where foot-and-mouth disease or rinderpest exists. Dedicated in 1979, it allows for the first importations of ruminants and swine since 1930. The Center can accommodate 400 cattle for the 3-month quarantine period.

Persons and baggage entering the United States from foreign countries are checked for prohibited agricultural materials—both plant and animal—at U.S. ports of entry by APHIS in cooperation with the U.S. Customs Service. Some agricultural products from foreign countries are permitted entry under restriction; over 200 processing plants in the United States are approved to receive and handle a wide variety of restricted animal products, byproducts, and related materials; e.g., animal semen. These establishments are under continuing surveillance to insure that the imports do not constitute a disease risk for our livestock. In addition, some 43 Canadian and 15 Mexican approved ports of entry are monitored regularly by VS port veterinarians.

Interstate Inspection—VS enforces standards (sanitation and health inspection) for livestock markets and the Federal regulations governing interstate movement of livestock. Over 2,000 livestock concentration points are checked for compliance with the regulations. Violators are prosecuted in U.S. district courts.

Swine Health Protection Act—A number of infectious and communicable diseases can be transmitted to swine through the feeding of raw or improperly cooked garbage: African swine fever, foot-and-mouth disease, hog cholera, trichinosis, tuberculosis, and vesicular exanthema. The practice of cooking food waste before it is fed to swine began on an organized basis in the early 1950's to combat a widespread outbreak of vesicular exanthema. When that eradication program was concluded in 1959, enforcement of regulations declined until 1962, when 16 States passed new laws that prohibited the feeding of garbage to swine: Alabama, Delaware, Georgia, Idaho, Illinois, Iowa, Louisiana, Maryland, Mississippi, Nebraska, New York, South Carolina, South Dakota, Tennessee, Virginia, and Wisconsin. Untreated garbage is a potential source of animal diseases, but properly cooked food waste is a valuable feed that hogs can use to provide additional protein for consumers; it also provides an option to cities, military installations, and others to dispose of a waste product economically. The common method of rendering garbage safe for consumption by swine is to boil the material for 30 minutes. In 1980, Congress passed the Swine Health Protection Act to regulate the treatment of garbage fed to swine. Waste from ordinary household operations fed directly to swine on the same premises is exempt.

National Poultry Improvement Plan—VS administers the National Poultry Improvement Plan, a voluntary State-Federal-industry cooperative program designed in part to control and eliminate certain egg-transmitted and hatchery-disseminated

diseases of poultry. The plan was founded in 1935 and is carried out in 47 participating States. As a result of the plan, pullorum and fowl typhoid essentially have been eliminated from chickens and much progress has been made toward control of *Mycoplasma gallisepticum* and *M. synoviae* in the poultry meat industry.

Veterinary Biologics—VS administers the Virus-Serum-Toxin Act of 1913, which requires that vaccines, serums, bacterins, antitoxins, and similar veterinary biological products be safe, pure, potent, and effective whenever they are shipped across State lines. Veterinary biologics are regulated primarily through the issuance of Federal licenses and by a system of inspection, investigation, and testing. Licenses are issued for each producing establishment and for each biological product. Regulatory activities cover virtually every aspect of plant operations, production, and testing. Product labels are reviewed to make sure that proper instructions are included, that necessary precautions are stated, and that no misleading or false claims are advanced. USDA veterinarians inspect production plants and investigate violations of regulations. This work is backed up by testing samples at the National Veterinary Services Laboratory. When conditions warrant it, VS can suspend marketing to protect farmers against worthless, contaminated, or harmful veterinary biologic products. During the development, production, evaluation and licensing of a new vaccine for use in animals, the minimal interactions of veterinary biologics industry and USDA include the following:

Manufacturer	**Veterinary Biologics/APHIS**
1. Propose a new vaccine.	
2. Develop procedures; test in the laboratory and in animals.	
3. Request license for experimental use.	1. Review request and supporting data; inspect plant; may issue license.
4. May apply for permanent production and sale license based on results of field trials and laboratory tests.	2. Review test results and production data; may issue permanent license.
5. Test each serial of product; maintain production records and user reports for government inspection.	3. Review results of serial tests and user reports; may test each serial at Federal laboratory; may continue the license.

Veterinary Diagnostics—The National Veterinary Services Laboratories at Ames, IA, provides laboratory support for the veterinary biologics program, import-export testing, and the various disease control and eradication programs, and serves as a reference assistance laboratory. There are six separate laboratories: biologics bacteriology, biologics virology, diagnostic bacteriology, diagnostics virology, pathobiology, and scientific services. The National Veterinary Services Laboratories maintain a readiness in case of an outbreak of exotic disease, make diagnostic reagents when they are not available commercially, train VS field force and State laboratory personnel, and provide consultation services for VS field stations, State diagnostic laboratories, university research personnel, and foreign scientists.

Disease Control Programs

Brucellosis—Control efforts began during the 1920's as independent State programs, but little progress was made until a national test and slaughter program was launched in 1934. Calfhood vaccination with Strain 19 was added to the program in 1940. In 1954, advances included the brucellosis ring test for inexpensive screening of dairy herds and the market cattle testing program to monitor the disease in beef herds. In 1980, Strain 19 vaccine of reduced dosage was made available, and in 1982, a new State rating system, based on the amount of infection, went into effect.

The eradication program for swine proceeded concurrently with the cattle program. Surveillance at slaughter is used to locate infected herds, which are then freed of brucellosis by test and slaughter procedures or by depopulation and restocking. States are classified in three stages, with stage III States declared free of the disease.

The incidence of brucellosis in cattle has been reduced to about 0.4 percent (1982); most infections are concentrated in cattle in 10 southeastern and south-central States. The incidence in swine is even lower - less than 0.1%. The disease has not been found in goats for over 10 years.

Cattle fever ticks spread bovine piroplasmosis, a severe and often fatal disease of cattle. In 1906, when a nationwide eradication program began, the disease was costing $40 million annually; that loss would be equivalent today to more than $1 billion a year.

Today's program includes a permanent quarantine zone along the Rio Grande River from the Amistad Dam near Del Rio, TX, to the Gulf of Mexico. Biweekly inspection of livestock within this zone serves as a barrier against stray cattle from Mexico that might be carrying ticks. All cattle and horses leaving the quarantine zone must be inspected and given a precautionary dipping. Any ticks found are eradicated by systematic dipping of cattle and horses on the infested premises for a period of 5 to 9 months. Occasionally infestations are found outside the quarantine zone; the same procedure of systematic dipping is followed.

Cattle scabies is caused by tiny, parasitic mites that puncture the skin of cattle and feed on the body fluids released from the wounds. As mites increase in number, the hair falls out and much of the the body is covered with thick, crusty scabs, hence the name *scabies.* Scabies does not affect the wholesomeness of meat from infested cattle, but the intense itching results in severe economic losses, particularly in feedlots.

A program to combat scabies in cattle is carried out by VS in cooperation with the States. Infested cattle are quarantined and treated with pesticides to kill the scabies mites. Each outbreak is investigated to determine the origin of the infestation and any possible spread. VS maintains a laboratory for accurate diagnosis of each reported outbreak, and a chemical laboratory to help ensure that the proper concentration of pesticide is used when the cattle are dipped or sprayed.

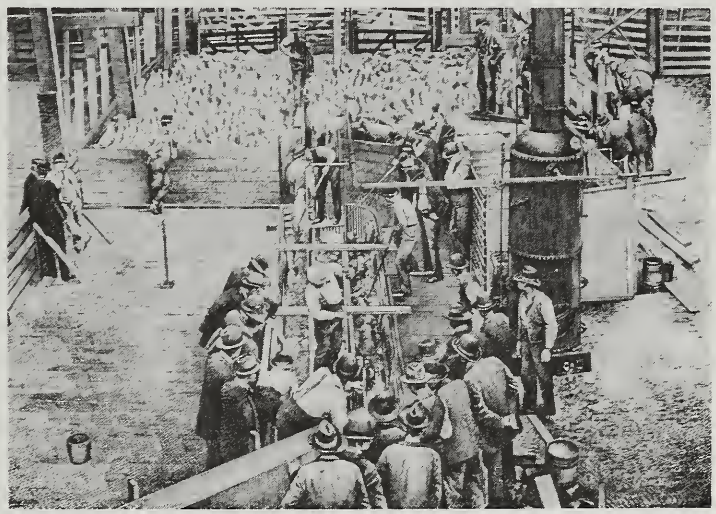


Fig. 4. Dipping sheep (about 1900) to control scabies (mange) in Arizona (left) (courtesy of the Arizona Historical Society), and at the Union Stockyards, Chicago, Illinois (right). The dipping plant, consisting of the vat, boiler (to heat the solution), pens, etc. cost about $2,500.00. Notice the BAI inspectors on observation platforms. January 1973 marked the official end of a "100-year itch"–the eradication of sheep scabies.

Tuberculosis in cattle, as a result of the eradication program, was reduced from nearly 5 percent to less than 0.03 percent, but it still exists in all sections of the United States. Since 1970, the disease was diagnosed in cattle in 35 States. Nowadays, most cases are found at slaughter plants by meat inspectors. When lesions are found that are indicative of tuberculosis, tissue samples are collected and sent to a laboratory for examination. If the results are positive, an exhaustive attempt is made to trace the infected cattle back to the herd of origin, which is then tested with tuberculin. If reactors are found, they are sent to slaughter and checked for lesions. If *Mycobacterium bovis* is found, every effort is made to liquidate the herd. Indemnity is paid to partially compensate the owner for losses. If the herd cannot be liquidated, it is held under quarantine and tested repeatedly until all evidence of infection is eliminated. Finally, veterinary epidemiologists continue the work by attempting to determine the date when the herd was probably infected, where the disease came from, and where it might have gone.

Swine tuberculosis is caused by the *M. avian* complex. It can result in rather heavy financial losses in some sections of the country because carcasses with lesions must be cooked or condemned at slaughter establishments. There

is, at present, no national program for swine tuberculosis.

Pseudorabies, also known as "mad itch" and Aujeszky's disease, has become a major threat to the swine industry. A highly virulent form of the disease appeared in this country in the 1960's. It can kill up to 100 percent of young pigs, but it causes few, if any, clinical signs in adult swine. Swine—the reservoir for the disease—can transmit it to cattle, sheep, and other animals, where it causes a fatal encephalitis with severe itching and self-mutilation—hence the name "mad itch." The disease does not affect man.

Vaccines are available to reduce economic losses, but they will not prevent swine from becoming infected and spreading the disease to other animals. Also, since tests cannot differentiate between vaccinated and infected swine, there is no way to be certain if a vaccinated animal is actually infected or just showing a reaction to the vaccine. Although the incidence has not been measured precisely, indications are that pseudorabies increased drastically during the 1970's. Pilot eradication projects are currently under way in Iowa and Illinois to test various methods of combatting pseudorabies.

Scrapie is a fatal disease of sheep and goats characterized by progressive degeneration of the central nervous system. It is caused by a filterable, transmissible, self-replicating agent even smaller than a virus. Affected animals rub, scratch, and become debilitated and incoordinated. Scrapie has an extremely long incubation period; exposed animals may carry the agent 18 to 42 months or longer before showing signs of the disease.

Scrapie was first diagnosed in the United States in 1947; since then it has been found in nearly 250 flocks in 39 States. It can be transmitted to at least five species of monkeys.

The cooperative State-Federal scrapie eradication program began in 1952. The program involves finding and diagnosing the disease, quarantining infected flocks, and slaughtering affected and exposed animals. Indemnities are paid for animals that must be slaughtered. Studies at Mission, TX, have shown that succeeding generations from scrapie-infected animals will develop the disease and that scrapie will spread to nonrelated sheep and goats held and bred on infected premises. VS is also concerned about similarities between scrapie and two diseases of man—kuru and Creutzfeldt-Jakob disease. Since 1975, sheep and goats exposed to scrapie have not been slaughtered for human consumption.

Wildlife also may affect disease control. The success or failure of most livestock disease programs is dependent upon whether the disease agent becomes established in wild animals. In 1924, an outbreak of foot-and-mouth disease in California was quickly eradicated from cattle but not before the disease spread to deer in the Stanislaus National Forest. Sportsmen strenuously opposed eradicating deer, sometimes at gunpoint, but the disease was eliminated after 6 months of cooperation between the U.S. Forest Service, the California Fish and Game Commission, and the BAI. The last deer showing signs of infection was killed June 10, 1925. Because USDA's responsibility for the health of animals does not extend to wild animals or birds, USDA veterinarians learned to rely on joint programs with the States. For example, during the campaign to eradicate exotic Newcastle disease from chickens in California (1971-1973), a major concern was whether the causative virus had spread into free-flying birds and thereby established a reservoir. Systematic collections of birds were made by State and Federal veterinarians and they were examined at the National Animal Disease Center for the virus. Of almost 10,000 birds, only 3 sparrows and 1 crow harbored the virus. Mourning doves, starlings, and migratory ducks and geese were not infected. The veterinarians concluded, therefore, that infection of free-flying birds did not interfere with the State-Federal program. The program was continued until the disease was eradicated in June 1974. Currently, the wildlife agencies of 13 southeastern States, the U.S. Department of the Interior, and VS/USDA maintain surveillance of diseases among wildlife and domestic animals. The results of the cooperation have had practical applications for the management of the nation's wild animals and birds, on production of wild and domestic animals, and for the policies of public health. Some examples include the following:

(1) Deer management in the Southeast was greatly enhanced through herd health procedures.

(2) Certain foreign game birds should not be introduced because they harbor diseases fatal to native game bird populations.

(3) Introduction of elk or mule deer is futile in most southeastern areas because white-tailed deer harbor a parasite that can gradually paralyze most other deer species.

(4) Wild swine populations throughout the southeastern United States frequently harbor important swine diseases such as brucellosis and pseudorabies.

(5) Brucellosis and leptospirosis, important cattle diseases, are not spread by white-tailed deer.

(6) Toxoplasmosis, infective to humans, is harbored by white-tailed deer, but the risk of infection from venison is probably no greater than from beef, pork, or lamb.

(7) Interstate translocation of raccoons is a questionable practice because of infectious diseases such as rabies, parvovirus, and canine distemper.

International Programs

Disease Intelligence Service—VS has a veterinarian stationed in Rome, Italy, who is responsible for monitoring the animal disease situation in Europe, the Middle East, and Africa. He also represents the agency in contacts with animal health officials in countries in those regions.

Foot-and-Mouth Disease Surveillance—Ever since the outbreak of foot-and-mouth disease in Mexico in 1946, the United States has recognized its vulnerability to disease from its neighbors to the south. Once this foot-and-mouth disease outbreak had been eradicated by a joint U.S.-Mexico effort, the two governments established a commission for its prevention. In the operation, the Mexican and U.S. governments both contribute personnel and financial resources to a program to investigate all reports of vesicular diseases, to develop and enforce quarantine laws to prevent the spread or introduction of foot-and-mouth disease or other foreign animal diseases, and to carry out an extensive eradication effort should an outbreak of foot-and-mouth disease appear.

Since 1970, similar programs have been established in all Central American countries and Panama to assist their efforts to prevent the introduction of foreign animal diseases and to prepare for their eradication should they gain entry. To meet this challenge, VS veterinarians have been assigned in Central America and Panama. In Panama, at its border with Colombia, the Darien Gap—an area of swampland, dense jungle, and the Darien mountain range—has thus far prevented the highway systems of North and South America from being connected. However, the Colombian government plans to complete the Pan American Highway through the Darien Gap, thus allowing greater movement of man and animals between the two continents. The United States has signed agreements with both Colombia and Panama to help prevent the northward spread of foot-and-mouth disease—which is present throughout South America—during construction and after completion of the highway. A zone free of the disease is being established on the Colombia side of the border, and a cattle-free zone has been established on the Panama side. Strict controls are in effect, with a vaccine buffer zone set up in Colombia between the infected part of the country and the free zone. VS has personnel in both countries to assist in the Darien Gap program.

Emergency Programs—The development and maintenance of efficient, productive, and competitive livestock industries requires an alert, aggressive, and scientifically sound national veterinary service. When European markets for U.S. livestock began to disappear following the spread of contagious bovine pleuropneumonia, Congress became sensitive to the constraints posed by animal disease and established the BAI. Since then, foreign pathogens—foot-and-mouth disease, and other infectious agents that could devastate our livestock industries—have repeatedly challenged the BAI and its successor agencies. Each incursion of a foreign animal disease into the U.S. required that the BAI train a new "Fire Department" with new authorities, resources, technologies and objectives. Then when a "Fire Department" brings the disease under control, eradication becomes a possibility to be considered and usually another unit must be formed.

In the late 1950's and throughout the 1960's, several events precipitated the establishment of an arm of the ARS identified as "Emergency Programs" responsible for developing and maintaining the ability to react to foreign animal pathogens. African horse sickness spread from its normal habitat in East and South Africa throughout the countries of North Africa and the Near East. African swine fever extended into Western Europe during the early 1960's and to Cuba in 1971. Foot-and-mouth disease repeatedly appeared in countries that had spent vast sums on the disease. Venezuelan equine encephalomyelitis marched through the countries of northern South America, through Panama, through Central America and Mexico, and entered Texas in 1971. And exotic Newcastle disease broke out in California chickens (1971). All these occurrences demonstrated the need for new technologies for dealing with outbreaks of exotic animal diseases. "Business as usual" could not cope with such challenges. Therefore, USDA formed a special

task force, Emergency Programs, with special resources for funding and recruitment, with clear and adequate legal authorities, and with a highly trained, specialized staff. Any report of an "emergency" disease activates the task force to identify and assess the danger and to isolate the outbreak until the appropriate control procedures are instituted.

VS has a list of some 40 exotic diseases with which it is prepared to deal. Seventeen of these are in the *priority one* category—those considered most dangerous to the nation's livestock and poultry, as follows: African horse sickness, African swine fever, bluetongue (foreign strains), bovine babesiosis, East Coast fever, exotic Newcastle disease, foot-and-mouth disease, fowl plague, heartwater, hog cholera, lumpy skin disease, Rift Valley fever, rinderpest, San Miguel sea lion virus, swine vesicular disease, Venezuelan equine encephalitis, and vesicular exanthema. VS has a surveillance system to quickly detect and diagnose any exotic animal disease in this country. Specially trained veterinarians are stationed throughout the United States so they can immediately investigate each suspected disease and submit specimens to the appropriate laboratory for diagnosis. When a foreign disease is diagnosed, a Regional Emergency Animal Disease Eradication Organization (READEO) set up in each of the five VS regions, carries out field operations. READEO's were established on the theory that a preselected, pretrained unit of specialists can eradicate a disease more rapidly and efficiently than a group pulled together at the time an outbreak occurs. Federal, State, university, military, and other sources have been tapped for persons to fill key positions. These persons are trained in their specific responsibilities and are prepared to respond quickly when an outbreak occurs. The State veterinarian of the affected State usually serves as co-director of the task force.

VS maintains an awareness of the worldwide animal disease situation. It has a highly sophisticated information system to deal with any outbreak, including a continuing search of the world's literature in the fields of interest; reading, indexing, and coding relevant articles; and transferring them to microfilm. In response to requests, stored information—including maps—can rapidly be retrieved and disseminated by the Emergency Programs Information Center in Hyattsville, MD.

Field reports of disease outbreaks are fed into a central computer that can give out pertinent information by State or region, type of outbreak, species of animals, and so on. Training programs and test exercises are held periodically to make sure that each member of the task force knows his or her job. In these ways, USDA veterinarians stand ready to protect the national herd from exotic animal diseases.

EPILOGUE

America was fortunate in the beginning. This was the "new land"—free of the many devastating animal diseases that plagued Europe, Asia, and Africa. But the arrival of a diseased cow in the port of New York in 1843, however, was the first of a series of animal plagues, and to control them, the BAI was created in 1884. It succeeded brilliantly—and its proud traditions continue today among the veterinarians of USDA.

Early on, the BAI affected veterinary medicine in a major way. The introduction of scientific methods for disease control and rigid standards for education and professional conduct rapidly transformed the individualistic practitioners of the 19th century into today's broad, strong profession. But when the BAI broke up, the Federal veterinarians were dispersed into the divisions and their influence on the profession was greatly diminished. Often isolated from their colleagues, preoccupied with assigned duties, yet striving toward similar research or regulatory goals, their diversity leveled off and many of them no longer ventured into the main stream of veterinary medicine—education and professionalism.

Animals are the dominant segment of agriculture—the world's oldest and largest industry. Over thousands of years, natural and artificial selective pressures have influenced the evolution of domestic animals toward our present specialized breeds. To meet economic pressures, farmers sometimes apply the newest technology to cattle and swine confined in very intensive (and stressful) situations without adequate testing, and "production disease" results. Modern breeding/feeding methods have initiated a series of new animal "diseases" that are now being recognized; e.g., genetic disorders, porcine stress syndrome, mastitis, and ketosis. In the future, Federal veterinarians must combat a profusion of infectious, noninfectious, and stress-related disease, study their causes, treatment and prevention at advanced levels of molecular biology, and maintain their vigilance against foreign animal diseases.

As the maintenance of animal health becomes more complex and requires ever greater specialization among veterinary researchers, management of the Federal forces will become more critical. The successful use of science depends more on the overall quality of management rather than the degree of scientific knowledge. High ability is in short sup-

ply. If too much is devoted to research, there may be too little to sustain its effective application. Nevertheless, the efficiency of animal production will continue to increase if the newer knowledge is promptly reduced to practice and if technological needs continue to be met. Among the latter needs are several vaccines and diagnostic reagents, increased disease-resistance through genetic engineering, an evaluation of toxic chemicals that may be entering the food chain, and methods to study multiple or sequential causes of animal diseases.

In the future, Federal veterinarians can anticipate new responsibilities, perhaps in entirely new fields, or perhaps through an expanded animal welfare program to include some measure of protection of "animal rights." Since animals have the capacity to suffer psycho-physically, some people contend that they should have full consideration of their rights, which are the satisfaction of their species' needs and wants. The debate over animal rights continues; a resolution is not in sight, and so the future role of the USDA veterinary force is uncertain but not uninteresting.

America's animal health is no accident. It is the result of a team effort—good husbandry by farmers and ranchers, excellent professional care by practicing veterinarians and scientists and organized State and Federal efforts to control and eradicate animal diseases based on valid research information. For a hundred years, USDA veterinarians and scientists have kept pace with developments in the livestock industry. With pride in the achievements of our predecessors and awareness of our capabilities, we face the uncertainties ahead with confidence that the USDA veterinary force can respond and adapt to meet the challenges of the future.

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PART III
ANIMAL HUSBANDRY—ANIMAL SCIENCE

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During the century since the establishment of the Bureau of Animal Industry (BAI) in 1884, the art of animal husbandry has been supplemented by animal science. Animal science, which includes nutrition, physiology, breeding, reproduction, environmental management, and product processing and quality, also includes the basic biological, chemical, and ecological sciences underlying these applied sciences. But the art of husbandry—the productive relation of the manager and the flocks and herds, their mutual responses and interactions—still remains essential. To the extent that science has displaced husbandry, it will be necessary to replace husbandry. According to an old proverb, "The eye of the master fattens the cattle." That is still true.

During this past one hundred years, animal science has provided the basic concepts and supporting information for animal production and product processing—ideas and data which steadily increased production efficiency, product quality, and variety for all classes of food animals and poultry. Horse and pet animal husbandry also have benefitted.

Research was at first based on testing—validating or discarding traditional practices of livestock and poultry producers. Exploratory research developed new information: Mendelian demonstration of segregation and recombination of genetic traits, energy metabolism, protein requirements, vitamins, minerals, hormones, behavioral relations and, finally, integrated systems. Research in BAI and its successor agencies has contributed substantially to the several-fold increase, for example, in milk produced per cow and in eggs per laying hen, and in the comparable increase in productivity of meat animals and poultry. This part of the BAI history is organized chronologically into four periods: 1884-1924, 1925-1948, 1949-1972, and 1973 to today. . . and tomorrow.

Period one begins with the establishment of the BAI and ends with the period of agricultural depression following World War I. Period two ends with the immediate post-war adjustment after World War II and the initiation of research programs under the Research and Marketing Act of 1946. Period three ends with the decentralization of research administration and the shift from species orientation toward discipline and interdisciplinary organization. Period four brings the transition from the art of husbandry to the sciences and technologies which have supervened, bringing to the fore again the necessity of understanding the whole animal, its nature and nurture, and the ecology of animal and animal-human agroecosystems.

PERIOD ONE: 1884-1924
EXPLORATION

During the exploratory period of BAI, information on successful practices of livestock producers was collected and disseminated. Information on the potential utility of animals foreign to American farmers—the Barbados hairsheep, ostriches, zebras, as examples—was gathered in the countries of origin and published in the United States and the animals were introduced into this country and tested. Research was begun in the development and application to production of poultry and livestock of the then-new sciences of nutrition and genetics. The science of bacteriology began to be applied to assure the safety of the U. S. milk supply and to extend the preservation of butter.

The act of May 29, 1884, which established the Bureau of Animal Industry, stipulated the duties of the chief ". . . whose duty it shall be to investigate and report upon the condition of the domestic animals of the United States, their protection and use. . . ." Pursuant to that mandate, the annual reports of chief D. E. Salmon included several relevant accounts. BAI agent J. B. Grinnell, of Grinnell, IA, estimated that there were about 8 million cattle in the Cornbelt and a total of about 30 million west of the Mississippi. He estimated that total cattle population had increased about 60 percent in the preceding decade and could continue to increase at about the same rate in the next decade. He recommended that ranchers be permitted to lease public lands for grazing despite the current and growing homestead policy.

Another agent, H. M. Taylor of Colorado, reported in 1888 that the influx of settlers since 1884 had reduced the amount of public land available for cattle grazing by a third, preempting many better-watered locations. He noted a

sharp decline in sheep raising, due to low wool prices. Of the sheep industry in arid areas that winter, he said that feed was so scarce, "The matter is of great surprise to me that, under the range system, sheep exist at all."

Agent E. W. Perry of Illinois in 1889 reported on cattle in the USA as purebred, native, and grade; there were about 147,000 purebred, of which almost 100,000 were shorthorns. He reported an average increase of 56 percent in milk production by progeny of native cows mated to purbred dairy breed bulls, compared to production of progeny of cows mated to native bulls.

Other reports were issued before the Bureau acquired professionals designated as experts in animal or poultry husbandry. E. W. Allen, Bureau editor, prepared Farmers' Bulletin 22, on feeds and feeding, an excellent compendium of the then available information in written and tabular detail.

G. F. Thompson, editorial clerk of the Bureau, prepared an interesting and well-written report in 1900 on the Angora goat, its nurture and productivity. There were then about 400,000 in the United States.

Occasionally animal research was international. A hybrid zebra was produced from a mating of a zebra stallion and a jenny in 1910, the first such event in the United States. The zebra stallion was a gift from King Menelik of Abyssinia to President Theodore Roosevelt. The hybrid was described as of superior vigor with potential utility (Houck, 1924).

Research Administration and Organization

Animal and poultry husbandry in the Bureau of Animal Industry were administered by the Bureau chief from 1884 until about 1900, when the Dairy Division was formed under H. E. Alvord, Chief. Research in livestock and poultry was initiated in Bureau laboratories in Washington and in field stations with guinea pigs at Bethesda, MD; with hogs, in 1905; and poultry, in 1906, at Halethorpe, MD. In 1909, B. A. Rawl became the Dairy Division chief and George Rommel the first animal husbandman. An Animal Husbandry Division, with Rommel as chief was formed in 1910.

Major research facilities were established at Beltsville in 1910 for dairy, horse, sheep, swine, cattle, and poultry. The Morgan Horse Farm, at Middlebury, VT, was acquired by gift. An ostrich farm in Glendale, AZ, was later converted to chicken research. In 1915 the Western Sheep Experiment Station was established by transfer of public land to USDA. Beef cattle research was carried on at the Ardmore, SD, Bureau of Plant Industry Field Station in 1917. In 1924 the Range Experiment Station at Miles City, MT, was established when land at Fort Keough was transferred from the War Department.

Highlights

Highlights presented throughout this part of the BAI history have been selected for one or more of the following reasons: (a) they were important firsts; (b) they were basic to understanding important problem areas; (c) they raised new, important questions. In all cases, the person or persons who are named worked with other unnamed persons to whom credit also is due—for example, animal caretakers and laboratory technicians, who are especially important. (I remember the occasion of a Superior Service Award to swine herdsman Jim Gaither. In response to the award, he said, proudly and appropriately, "I thank you for this award. I deserved it.")

Highlights of this period of BAI history include basic research in energy metabolism and population genetics and applied research resulting in the Dairy Herd Improvement Association (DHIA), in increased shelf life of butter, and in solving the problem of "soft pork."

Energy metabolism research, begun in 1898 in cooperation with Henry P. Armsby at Pennsylvania State University, was continued by E. D. Meigs, H. A. Cary, Lane A. Moore, and Paul Moe and their colleagues. Application of results of this research has continually improved the nutritionally and economically efficient feeding standards for dairy and meat animals and poultry.

Population genetics, the scientific basis for livestock and poultry breeding, began with the basic genetic research with guinea pigs carried on by Sewall Wright and his colleagues at Beltsville from 1905 to 1925. Subsequently, many other geneticists both inside and outside USDA have used this discipline to describe, elaborate, and test systems of breeding for improving productivity of livestock and poultry. Currently, the work of Gordon E. Dickerson (since 1940) at the Meat Animal Research Center, Clay Center, NE, is outstanding. Genetic research at Beltsville and other loca-

tions, begun in 1906, as well as USDA assistance in dairy records analysis and sire proving, has contributed to a major degree to the increase in milk production per cow in herds of Dairy Herd Improvement Association members. This increase has yielded a notable industry achievement in productivity.

Sewall Wright

Dr. Wright conducted research on livestock and poultry breeding at Beltsville, MD, from 1905 to 1925.

Butter research during this exploratory period provided a solution to a serious food problem—a short shelf life for butter. Research by Lore A. Rogers and his colleagues at Beltsville demonstrated that the traditional use of sour ripened cream for butter making shortened shelf life of the butter as compared with sweet-cream butter. A major change in butter making followed.

Soft pork was a long-standing problem of the meat industry. Research by Orville G. Hankins and Ned R. Ellis, with the cooperation of many State experiment stations and swine industry colleagues, demonstrated that feed fats are stored as such in pig fat. When fed to pigs, peanut and soybean meal, which contain fat that is liquid at room temperature, result in soft, oily carcasses.

Cooperation With The States

The pattern of BAI-State cooperation in research was initiated in 1897 in the study of energy metabolism of beef cattle by H. P. Armsby at Penn State. In the period 1900-1915, cooperation in poultry research was established with the Maine experiment station, in beef cattle research with the Alabama station, in horse research with the Colorado station, in sheep research with the Wyoming station, and in dairy breeding improvement with the Michigan station.

Extension work in the South emphasized the subsistence production of meat, milk, and eggs as supplements to cash cotton. In 1904, the Bureau contracted with the Alabama Agricultural Experiment Station for studies intended to increase beef production (Houck, 1924). In 1911, livestock extension work was set up in Louisiana, and in 1912 poultry extension work was begun in Virginia and other States. Livestock extension work increased in tick-free areas of the South in 1914 in a program that continued until 1919.

Acute problems of drought also were attacked by cooperative forces. In 1919 through 1921, the Bureau of Animal Industry, in cooperation with the States, transportation and marketing industries, and ranchers and farmers, moved about 450,000 cattle and 750,000 sheep from drought-stricken areas of the Great Plains to market or to pasture.

There has been the closest Federal and State extension cooperation with the Bureau in national research and extension programs—in dairy production, especially through DHIA; in animal husbandry, led by C. D. Lowe; in meats, under K. F. Warner; and in poultry, directed by H. L. Shrader. (The persons named all were members of the Federal Exten-

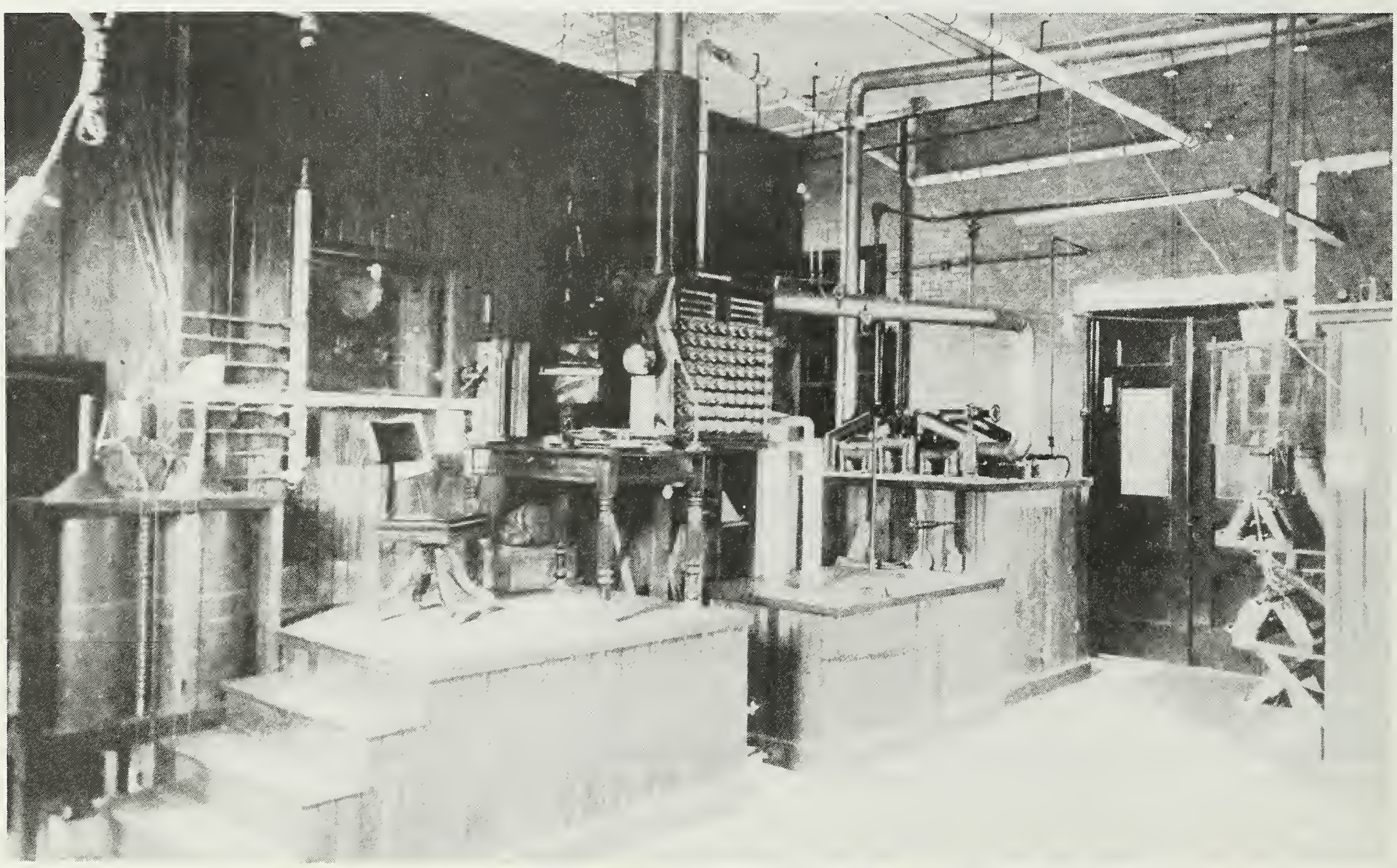
sion Service or were dairy extension workers.)

Beef Research

In 1901, George Rommel was appointed as the first animal husbandman in BAI. Rommel published a description of the principal breeds of beef cattle in the United States at that time—1902. He included Shorthorns, Aberdeen Angus, Devons, Galloways, Sussex, Red Polls, and Polled Durhams—the latter two breeds as dual purpose. He noted that Brown Swiss, while principally dairy cattle, fatten well and have considerable value as beef.

In 1907, per capita beef consumption was 90 pounds, but by 1921 it had dropped to 70 pounds. Cattle numbers, meanwhile, had remained stable from 1895 to 1920 at about 70 million. Partly by application of production and product research, however, cattle numbers now have increased to recent levels of about 114 million and beef consumption to about 106 pounds per capita.

Energy Requirements of Beef Cattle—In 1897, H. P. Armsby suggested to Secretary James Wilson the need for metabolic calorimeter studies with livestock. In the following year an Institute of Animal Nutrition at Pennsylvania State College was established under Armsby's leadership, and for more than 20 years he continued to head the institute. Until 1920 it was jointly funded by USDA and the college. Armsby died in 1921 (Houck, 1924). The research at the Institute was made with nine steers. Each test consisted of 21 days: 11 preliminary days to make the subject animal adapt to the calorimeter environment, followed by 10 days of quantitative collection and analyses of feces and urine. Heat production was measured on days 18 and 19 of the period. The studies were conducted in an Atwater-Rosa-type calorimeter. Gross energy of feedstuffs and of feces and urine were directly determined, as were carbon and hydrogen in the combustible gases given off by the subject steer. Carbon dioxide and heat production were measured, but not oxygen consumption.



The respiration calorimeter used by H. P. Armsby for experiments in animal nutrition.

Ten years of research at the institute, 1902-1912, were summarized by Armsby in 1915. In 1913 he had published a book which used data from the institute and data from earlier research by Kellner in Germany as the basis for estimating feed requirements and standards for maintenance and production. The book, in this and later editions, was widely

used as a text and reference. It contains his formal definition of metabolizable energy as that portion of chemical energy not lost in excreta (methane, feces, and urine) (Armsby, 1913, p. 270).

Feeding Practice—There was—and still is—very wide variation in beef cattle feeding practice. E. A. Cotton and J. S. Cotton visited 1,000 farms and obtained records for 478 Cornbelt farms. They divided the data into four classes according to the quantity of corn-equivalent units (CEU) consumed by the average beef cow during 163 winter days and they estimated the year-long cost of producing a weaned calf for each class. Among the four feeding-plane classes, they found no difference in percentage of calf crop. During the spring, summer, and fall periods, the cows were pastured at the same cost for the four classes. The year-long cost per weaned calf varied from $30 for the group on the lowest CEU winter intake to $43 for the highest CEU intake group. The most economical feedstuffs, as principal winter feeds, were corn stalks and oat straw.

Pure Breeding—In 1919, under the leadership of the Bureau's editor, Dallas Burch, the Bureau launched a national "Better Sires; Better Stock" program to increase the use of purebred sires. The program advocated the exclusive use of purebred sires, citing the higher value, and productivity of purebred beef steers was estimated to get $30 more per head than scrubs in the market. Purebred milk cows were estimated to produce 50 percent more milk than scrubs. Use of purebred sires was assumed to increase pig production 15 percent, and standard bred roosters to increase egg production of their progency 50 percent. Only 3 percent of the cattle population consisted of registered purebreds, although individual purebreds were three times as valuable as nonpurebreds. The objective of purebred cattle breeding was the production of sires which transmit to their offspring early maturity, thick fleshing, and the ability to use grass, roughage, and grain economically.

In 1920, Burch reported that 3,243 livestock owners were cooperating in the program. The number of participants grew to more than a hundred in each of 113 counties by 1926.

Dairy Research

Early reports from the Dairy Division include a report by the first chief, H. E. Alvord, on the dairy industry. He reported that milk cows had increased from about 13.5 million in 1884 to 17.1 million in 1899. In the latter year, about 10 percent of the milk produced was sold from farms as whole milk. B. H. Rawl, the next chief, worked in the southern States organizing dairying from 1905 until 1909, when he became division chief. It was he who established the Beltsville dairy farm, herd, buildings, and equipment. As chief he actively supported research in nutrition, breeding, and milk products. He resigned in 1921. The division became the Bureau of Dairy Industry in 1924.

Dairy Product Research—In 1908 Alvord and R. A. Pearson reported the results of a survey of the milk supply of 200 US cities. They found a great deal of regional variation in milk consumption. The average daily consumption of fluid milk was about ⅔ pint per capita. Four large southern cities averaged 0.38 pint; large northern cities averaged more than 0.80 pint. They reported improvement in quality since the advent of the glass milk bottle, but stated that they were too heavy, short-lived and expensive; the needed "ideal package, light, clean, safe, and so cheap as to be used only once and then destroyed, is yet to be found." (Alvord and Pearson, 1908, BAI Bull. 46).

A milk train and retail delivery system, about 1900-1910.

Concern continued for the effectiveness of pasteurization, as practiced, especially as related to colon bacilli of bovine fecal origin and of spore formers. In 1915, S. H. Ayers and W. T. Johnston, Jr., reported that 62.8ºC was the critical temperature for bacterial destruction by pasteurization. C. Thom and S. Ayers in 1916 reported that a few spores survived 30 seconds at 62.8ºC (the Holder process). They stated that the flash process, 79.8ºC for 30 seconds, destroyed practically all spores found in milk.

An outstanding research achievement during this period resulted from the research of L. A. Rogers and his colleagues on factors affecting the keeping quality of butter. The research was initiated because hermetically sealed canned butter maintained without refrigeration by the USA Armed Forces in many locations developed off-flavors, odors, and unpleasant consistency. Research over the 10 years 1902-1913 established that butter made from sour cream, no matter how sterilized, deteriorated. Butter from pasturized sweet cream, hermetically sealed, did not. Their work resulted in a general shift in practice from sour (ripened) cream to sweet cream in butter making.

Rogers lived a hundred years, honored and full of vigor. His eulogy In the *Journal of Dairy Science*, contains the following quotation from his Borden Award citation: "His discovery that butter made from pasteurized sweet cream had better keeping quality than butter made from sour ripened cream, has revolutionized the theory and practice of butter manufacture and has saved the industry millions of dollars."

Dairy Herd Improvement—Cooperation among the dairy farmers, State agencies, and the Dairy Division of BAI in "cow testing" to improve milk production began in 1906. The first association was formed in Newago County, MI. During its first 10 years, average milk production of cows enrolled in the program increased from 5,354 pounds per cow to 6,637 pounds.

Participation in Dairy Herd Improvement Associations and in milk production of participant cows grew steadily. McDowell described the average association as consisting of 26 farmers; collectively, they employed a person to weigh and record the quantity of feed eaten and milk produced by each cow per day each month. The tester compiled annual records which were then collated by State extension services and transmitted to the BAI Dairy Division for summary analyses and reporting.

The Dairy Division advocated the use of proved sires—proved to transmit superior milk production to their daughters. The Division further cooperated by providing bulls for test to cooperating State experiment stations and to farmers who would keep daughters' milk records for proof.

Proof requires several years and many bulls fail to improve daughters' milk production above that of their dams and contemporaries. But use of sires that do transmit superior genetic capacity for milk production was established as a method of choice for improvement of herd production.

Poultry Research

In 1896, USDA published its *Farmers' Bulletin* 41, "Fowls—Care and Feeding," prepared by C. G. Walton, of Pennsylvania State University. Information on care and feeding was appropriate but labor intensive. He advised a morning meal of equal parts ground corn, oats, wheat bran, and mids, mixed with milk—wet, not sloppy—plus a pound of meat meal for each 25 hens. Among his interesting observations was that too much buckwheat produces pale yolks; it does. Further, a little linseed meal helps grow good feathers; feeding weed seeds to chickens poses less danger of spreading noxious weeds than feeding them to other classes of livestock; some kind of green food is necessary for best egg production—he recommended mangelwurzel in winter, clover in spring, dwarf Essex rape in summer. How times have changed! Now formulated feeds are supplied automatically to confined layers.

In 1904, C. W. Brown in the BAI Biochemic Division reported research on digestion in poultry (Brown, 1904). He conducted digestion trials with corn, oats, wheat, and meat as single ingredients. He used birds wearing an ingenious harness and excreta-collection bag which he devised. His report contains 120 references to the literature.

The Bureau of Animal Industry also was interested for a short time in ostriches, which were a source of plumes for millinery and costume use. In 1910 there were about 200,000 ostriches in the country, 80 percent of them in Arizona. But ladies' fashions changed and the industry declined. An ostrich experimental farm was operated briefly at Glendale, AZ, but the program at the farm soon was changed to chicken research.

In the *Yearbook of Agriculture* for 1916, A. S. Weiant reported on turkey production in the United States. According to Weiant's article, about 10 percent of all the country's turkeys during the period 1900 to 1915 were produced in Texas. There many flocks were used to glean grain fields and to destroy grasshoppers. Later in the season they were grain fattened for the Thanksgiving or Christmas market. There were turkey drives to market reminiscent of the cattle drives of the 1870's.

At the second annual meeting of the American Association of Instructors and Investigators in Poultry Husbandry (1916), Harry Lamon, the first poultry husbandman in charge of poultry research at Beltsville, made a summary report on the industry. His report included notes on the centers of poultry production, as follows: Single Comb White Leghorns at Petaluma, CA, and Vineland, NJ; and Single Comb Rhode Island Reds at Little Compton, RI.

In 1917, Lamon.and Alfred Lee made a detailed report of their 3-year, 76-pen study of feeding for egg production. A basal grain/grain byproduct diet, without supplement, fed to grass-range hens was compared with the same basal supplemented with cotton seed meal, menhaden fishmeal, or beef scraps fed to confined layers. The unsupplemented range birds laid an average of 90 eggs per hen year. The supplemented confined hens laid 137 eggs per year. As a supplement, menhaden fishmeal was found equal to beef scraps. Hens fed cotton seed meal produced eggs with mottled yolks.

Lamon selectively bred a line of general-purpose chickens at Beltsville that laid white-shelled eggs, while other general-purpose chickens produce brown-shelled eggs. In 1921, the Secretary of Agriculture officially approved the name "Lamona" for this new breed. The breed was not widely used by producers.

M. A. Jull came to Beltsville in 1924, and during that year he published his colloquy, "The Development of Poultry Research." He stated, "Science exists to illuminate man's path through life and to lighten his understanding." He said that productive research must be based on a clear conception of the nature of the problems to be solved, the methods for obtaining relevant data, and presentation of the data in clear, understandable form. "There must be vision, for data are secured for use and not for themselves." Jull brought leadership that made the next 13 years, his tenure at Beltsville, a highly productive period in poultry research there.

Sheep and Wool

Lamb and mutton consumption in the United States from 1912 to 1921 averaged 6.1 pounds per capita. However, depressed prices for lambs and for wool in 1920-1921 caused the liquidation of many flocks.

Early exploratory research with hairsheep (Barbados Black Belly) ended at Beltsville when the sheep barn burned in 1915. There is current interest in the potential of these prolific sheep for lamb and mutton production without the seasonal problem of wool harvest.

Research with sheep was established at Middlebury, VT, and at Beltsville, MD, and cooperatively at Laramie, WY, and at Dubois, ID, in that order. The research at Middlebury and at Beltsville was planned to relate to economic problems first, science second. The flocks at Beltsville were established in 1915; "Sheep Acres" consisted of 100 tillable acres arranged in forage-crop fields to be used rotationally. Breeding flocks of Southdowns, Shropshires, Hampshires, and Corriedales were established to study ways of maximizing lamb production chiefly from forage. Corriedales were imported from New Zealand in 1915; the Corriedale was derived from 30 years of selective breeding for high wool and lamb yield from initial crosses of Lincoln and Merino sheep. A Corriedale flock was established at Dubois for comparative studies with Rambouillets, the most numerous breed in the Western range sheep industry.

The Dubois, ID, Sheep Experiement Station was established in 1915, when President Wilson assigned 28,160 acres of summer-fall range for sheep research; in 1922, 16,250 acres of summer range on the Targhee National Forest was assigned by President Harding's executive order. In addition to the comparative studies of Corriedales and Rambouillets, a new breed, the Columbia, was developed at Dubois. The Columbia was derived by selective breeding for high yield of lamb and wool under range conditions, from original crosses of Lincoln and Rambouillet. The Columbia excels as a dual purpose sheep under the good range conditions for which it was developed.

Before the development of synthetic fibers, wool ranked next to cotton as the most widely used textile fiber. Demand was especially heavy during war time. But following World War I, prices dropped very low and many sheep flocks were liquidated.

Basic research on wool and methods of measuring wool quality was begun at Beltsville in 1919. Suitability of wool for clothing and rug use depends on fiber length and diameter and on fiber elasticity, tensile strength, and breaking strength. J. I. Hardy (1919) reported that as the ambient relative humidity increases from 40 percent to 80 percent, the elasticity, tensile strength, and breaking strength also increase. Evaluation of fleece for these traits, therefore, depends on their measurement at the same relative humidity. Tensile strength also is correlated with fiber diameter.

Pork

G. M. Rommel described the American hog industry in 1902, making the prescient comment: ". . .at present, the hog that sells for the highest price on the markets of Central West, is the hog of the lard type. Nevertheless, competent authorities are of the opinion that the consumers' demand in the not far distant future will undergo a change and require a cut of pork that contains relatively more lean and less fat."

This change had not occurred when E. Z. Russell and his colleagues reviewed, in the *Yearbook of Agriculture* for 1921, the status of the hog industry and its history in the United States; they reported that lard consumption for the preceding 5 years was 12.5 pounds per capita. Lard production in 1921 was more than 24 percent as great as pork production, the same proportion as in 1907. There had been, however, a trend away from the small, chubby hog which dominated the hog industry before 1900 toward larger, more prolific types. Hog numbers had increased from 27 million in 1890 to 62 million in 1920. In 1921, 80 percent of all farms raising hogs slaughtered them for home use; only 40 percent sold hogs. Hogs were used generally by beef feeders to follow steers, recovering their feed from steer manure. "Soft pork," and the associated lard, which was liquid at room temperature, were a serious problem in the Southern and Southeastern States.

Hog research was initiated at Beltsville about 1911, and in cooperation with USDA's Bureau of Plant Industry at the Dryland Station at Huntley, MN, at Newell, SD, and at Mitchell, NE.

Research on the soft pork problem was initiated in 1922. BAI scientists cooperated with other scientists in 11 States in highly productive research that demonstrated causes, processes, and feeding practices resulting in soft pork. Soft pork was associated with peanut feeding, but also with feeding full-fat soybeans and slaughter of lightweight, poorly finished hogs. Ned Ellis and Orval Hankins conducted research in depth on fat deposition and fat characteristics in pigs fed rations low in fat. Pigs were slaughtered at 10, 30, 75, 110, 170, and 225 pounds liveweight. Both the proportion of fat in carcass and saturation of the fat deposited increased as weight increased. Linoleic acid (polyunsaturated) proportion in the fat closely followed the amount in the feed.

Pigs fed low-fat diets synthesize principally saturated fatty acids, which results in hard fat deposited. Only 15 percent of carcasses of 20-pound pigs was fat, while 42 percent of carcasses of 225-pound hogs was fat. Hogs fed diets high in fat deposit fat of the same characteristics, and content of polyunsaturated fatty acids are the same as in the feed. Thus peanut-fed pigs yield soft pork. The eleven cooperating States provided 3,500 hogs, which were slaughtered and analyzed at the Bureau's meat laboratories in Beltsville (Ellis and Hankins, 1925.)

Horses

At the Colorado State Experiment Station horse breeding research was designed in 1904 to develop a carriage horse breed on an American foundation. A stud was established consisting of 18 mares selected phenotypically to be stylish, 15.3 hands high and 1100-1150 pounds in weight. A stallion of American trotting horse registry, 16 hands high and 1200 pounds in weight, was purchased to head the stud. Horse prices had risen for several years and increased market demand, for export as well as domestic, was foreseen.

In 1907, the U.S. Morgan Horse Farm was established through a gift of land by Joseph Batell, a Morgan horse breeder in Vermont. The ancestral stallion, Justin Morgan, was foaled in Vermont in 1793. The First Vermont Cavalry in the Civil War were mounted on Morgans, and Sheridan's ride was made on a Morgan. In 1921, the farm was presented with a statue of the original sire, Justin Morgan, the gift of the Morgan Horse Club. The Bureau established and maintained a stud of 60 individuals at the farm; research to improve the breed for work, riding and driving quality was continued by the Bureau until 1952, when the station was transferred to the University of Vermont.

From 1912 to 1920, the Animal Husbandry Division was responsible for selective breeding and placement of stallions used to sire horses suited for use by the Remount Service of the U.S. Army. The program called for 100 stallions

and 2,400 mares located regionally—240 in the Northeast, 1,200 in Central States, 360 in the Southwest, and 600 in the Northwest. The stallions were 10 Morgans, 25 standardbreeds, 15 saddlers, and 50 thoroughbreds. Stallions would be disqualified by any tendency to pace, rack, paddle in front, or sprawl behind. August Belmont, president of the Jockey Club, contributed two thoroughbreds, one of which, Octagon, was a notable sire. The USDA work showed the effective use of selective sires for production of remount horses. The horses, and responsibility for them, were transferred to the War Department in 1920. That department continued the breeding program until about 1950, when the Remount Service was discontinued.

In 1916, George Rommel, chief of the Animal Husbandry Division, stated that though livestock supplied most of the motive power on the farm—about 25 million horsepower--autos and trucks at that time were replacing horses for dray and road use. He thought that the effect of mechanical power on the future use of horse power on the farm could not at that time be predicted. World War I produced a market for many U.S. horses, but the postwar farm depression was followed by increasing farm mechanization and decline in farm-horse numbers.

Genetic Research

Genetic research with guinea pigs was planned in 1905 by Rommel and was conducted successively by R. J. Carr, E. H. Riley, and F. R. Marshall, and from 1915 to 1925 by Sewall Wright, then by Hugh McPhee and Orson Eaton. After 15 years of inbreeding research, records of about 34,000 individual guinea pigs had been recorded. Twenty-three families, bred brother to sister for many generations, produced 25,000 animals; random-bred control stock, 4,000; and crosses among inbred families, 5,000. There was a average decline in vigor elements including mortality, weight-for-age, regularity of reproduction, and resistance to tuberculosis.

Conspicuous differences in heritable traits, e.g. color, among families were increased by inbreeding. Marked improvement in vigor resulted from crosses between inbred families. There was a marked improvement in vigor of the first cross. Further improvement resulted from mating crossbred females to unrelated males. The net improvement in vigor resulted in progeny superior in vigor to the random-bred stock. Wright (1922) concluded: "It is believed that the results point the way to a important application of inbreeding in the improvement of livestock . . . .(B) starting a large number of inbred lines, important hereditary difference(s) . . . are brought clearly to light and fixed. Crosses among these lines ought to give full recovery of whatever vigor has been lost by inbreeding, and particular crosses may safely be expected to show a combination of desired characteristics distinctly superior to the original stock." This dictum is relevant to the subsequent research with chickens by Morley Jull and Charles Knox at Beltsville, with dairy cattle by Milton Fohrman, with swine by McPhee and Ralph Phillips, and with sheep by Ralph Schott, Claire Terrill, and their successors.

Wright and his colleagues also published analyses of the genetics of color in mice, rats, rabbits, guinea pigs, cattle, and horses. Wright is one of three persons generally credited with the establishment of population genetics. The other two are R. A. Fisher and J. B. S. Haldane of England. Wright spent 10 years in basic research with guinea pigs at Beltsville. This research by Wright and his colleagues developed methods for determining and expressing quantitatively the amount of inbreeding and the degree of relationship among individuals in populations, pedigreed in successive generations.

After he left Beltsville, Wright served with great distinction at the University of Chicago, and finally at the University of Wisconsin. In 1968 Wright said ". . . during the 10 years which I spent in the Animal Husbandry Division . . . conducting experiments in inbreeding and crossbreeding of guinea pigs and trying to relate principles of population genetics to problems of livestock improvement . . . I was developing my basic ideas." (Wright, 1968, p.2). Hundreds of scientific papers, by scores of population geneticists, have been published applying to livestock breeding with some success the principles developed by Wright.

PERIOD TWO: 1925-1948
DISCOVERY

The period 1925-1948 was a period of discovery and innovation for the Bureau of Animal Industry. Many vitamins were evaluated at Beltsville. The animal protein factor, later demonstrated to be Vitamin B12, was shown to be essential for hatchability of hens' eggs. The basic research on inbreeding and crossbreeding begun in the preceding period was expanded to poultry, beef and dairy cattle, swine and sheep, leading to wide application in the third period following.

This period, covering the depression of the thirties and the years of World War II, was a time of high research productivity. In 1925, the total USDA appropriation was $42.9 million, of which $9.7 million was for research. Despite (or because of?) the austerity imposed by drought and depression, research flourished in the nation. Secretary Henry A. Wallace came to office with a background of successful application of selective inbreeding and crossing produce hybrid corn. He provided aggressive leadership to research during the thirties. The Bankhead-Jones Act was adopted in 1935, authorizing and directing the Secretary to ". . .conduct scientific, technical, economic and other research into laws and principles underlying basic problems of agriculture in its broadest sense. . . ." Under this authority funds were appropriated and used to support basic research in cooperation with State experiment stations in animal breeding and genetics research with sheep, swine, and poultry.

Animal and poultry research facilities were modernized in this second period at Beltsville. This was a part of the Public Works Program of the Great Depression. Earl W. Sheets, chief of the Animal Husbandry Division, provided aggressive leadership during the planning and construction period. But funds ran out before construction was completed, and Sheets' services were terminated. The Animal Husbandry Division then was split into Animal Nutrition, under Paul Howe, and Animal Husbandry, under Hugh McPhee. This split in 1937 resulted in a corresponding division in poultry investigations, and this caused Morley Jull to leave Beltsville, to become head of the poultry department at the University of Maryland. Animal Husbandry and Nutrition were reunited in BAI in 1941 when Howe joined the armed forces.

Research Administration, Organization, and Facilities

The Bureau of Dairy Industry, 1924-1953, was headed by O. E. (Ollie) Reed, assisted from 1934 by Ralph E. Hodgson. The Bureau was organized into four research divisions: Breeding, Feeding, and Management was directed successively by R. R. Graves and Milton N. Fohrman; Dairy Herd Improvement was led by J. C. McDowell, then by J. F. Kendricks; Nutrition and Physiology was headed by E. B. Meigs, succeeded by C. A. Cary, then by Lane A. Moore; and the Dairy Products Division was under supervision of Lore A. Rogers, followed by G. E. Holm. Headquarters of the Bureau were in the District of Columbia, as were the dairy products laboratories, of which some were transferred to Beltsville about 1937, where all four divisions had offices and laboratories.

Breeding and management research was also conducted at Huntley, MT, at Lewisburg, TN, and at Jeanerette, LA, and, for a few years, at Hannibal, MO, and at Sand Hills Station, SC. Feeding and management studies were conducted at the Southern Great Plains Station, Woodward, OK, at the Northern Great Plains Station at Mandan, ND, and at the Dry Lands Experiment Station at Ardmore, SD.

The Animal Husbandry Division was headed by E. W. Sheets until 1937, when he was succeeded by Hugh C. McPhee. McPhee was made Assistant BAI Chief in charge of research in 1947, Theodore (Ted) Byerly directed the Division from 1947-1953. The components of the Division were as follows: Beef and Dual Purpose Cattle, Horses and Mules, Meats, Poultry, Sheep and Goats, Swine, and a Farmed Fur Animal section was transferred from the U. S. Department of the Interior about 1950. The Beef and Dual Purpose Cattle investigations were directed successively by W. H. (Bill) Black, R. T. (Scottie) Clark and E. J. (Ev) Warwick. Horse and mule investigations were directed by J. O. Williams, succeeded by S. R. Speelman. Orville G. Hankins directed the meat investigations. He was succeeded by R. L. (Dick) Hiner; Poultry direction was, successively, by Morley A. Jull, Berley Winton, T. C. Byerly, Herbert R. Bird, and Wade Brant; the Sheep division was under Damon A. Spencer, succeeded by Clair F. Terrill, Swine, under John H. Zeller; Farmed Fur Animals, under Charles E. Kellogg.

Genetics as a discipline was directed by Sewall Wright, who was succeeded by Hugh C. McPhee, Ralph W. Phillips, and Ralph G. Schott. Nutrition as a discipline was directed by Paul E. Howe, then by Ned R. Ellis.

Research with beef and dual purpose cattle was conducted at Brooksville, FL, Jeanerette, LA, Miles City, MT, Woodward, OK, and Ardmore, SD, with cooperative Federal-State industry research at several locations, including King Ranch in Texas and Sur-A-Bar farms in Missouri as well as Beltsville.

Horse investigations were conducted at Beltsville, at Miles City, and at Middlebury, VT. Mule investigations were made in Tennessee in cooperation with The Tennessee Agriculture Experiment Station. Meat investigation laboratories were at Beltsville, processing and analyzing research meats and meat products from many cooperating Federal and State stations.

Poultry investigations were conducted at Beltsville, at Glendale, AZ, and at Miles City, MT (transferred to Beltsville

in 1935). In 1938, research on breeding, environmental control and pathology of the avian leukoses complex was initiated, pursuant to the Bankhead-Jones Act, at the Regional Poultry Laboratory in cooperation with 24 Northeastern States.

Sheep and goat research was conducted at Beltsville, at Dubois, ID, at Miles City, MT, at Ardmore, SD, and at Middlebury, VT, and in cooperation with the Bureau of Indian Affairs at Fort Wingate, NM. Basic research in sheep genetics, pursuant to the Bankhead-Jones Act, began at Dubois in cooperation with the eleven contiguous Western States and South Dakota about 1938.

Swine research was conducted at Beltsville and Miles City. In 1938 a Bankhead-Jones swine breeding laboratory to conduct basic research on swine genetics was initiated in cooperation with the North Central States and Oklahoma with informal North Carolina participation. W. A. (Bill) Craft gently, productively, and ingeniously coordinated this research program. New locations for swine research after World War II are considered in Section 3. Termination of the Bureau of Dairy Industry and the Bureau of Animal Industry in 1953 had little impact on research at the investigation level.

Highlights

Among important firsts during this period is the demonstration of the high heritability of feedlot gain in beef cattle, first estimated by Bradford Knapp and Arne Nordkog at Miles City. The use of large type bulls in beef production has since become general to assure fast-gaining progeny.

Soil on tens of millions of acres in the USA and hundreds of millions of acres in other countries of the world, produce forage deficient in phosphorus relative to beef cattle requirements for reproduction. William H. Black and cooperators to the Texas Agricultural Experiment Station and the King Ranch demonstrated through research, 1937-1947, that phosphate supplements in drinking water is an efficient and economical correction, resulting in substantially increased calf crops.

Turkeys available in the nineteen-thirties were too large for single-meal family use. Selective breeding, 1935-1944, by Stanley J. Marsden and his colleagues resulted in the Beltsville turkey, a useful small white turkey which was quickly propagated by industry. Current annual production is about fifteen million such small-type turkeys.

The animal protein factor (APF) B12 , a factor contained in animal protein feed concentrates, was demonstrated by Theodore C. Byerly, Harry W. Titus, and Ned R. Ellis, in 1933, to be essential to hatchability of hens' eggs. Later, Herbert R. Bird and his colleagues proved that vitamin B12 is essential for survival of newly-hatched chicks. Today major use of soybean meal, supplemented with B12 , is made in poultry breeder diets. The B12 discovery has been a substantial contribution to the increase in the hatchability of hens' eggs from the 65 percent level to the current 85 percent level. This 20 percent increase means an annual saving of about 600 million hatching eggs valued currently at more than $60 million.

Induced ovulation in chickens was first accomplished by Richard Fraps and his colleagues at Beltsville. This was a step essential to understanding the complex hormonal and environmental factors regulating egg production and their possible manipulation to exceed the egg-a-day cycle of individual egg production.

Poultry artificial insemination (AI) is widely used by primary turkey and broiler breeders. The techniques used rest on the research of William H. Burrows and Joseph Patrick Quinn at Beltsville, 1935-1945.

Research on the objective measurement of meat quality made by Orville Hankins, Paul Howe, Kenneth Warner, and their colleagues, and State and industry cooperators, resulted in the Warner-Bratzlee shear test for tenderness and the use of the 9-10-11 rib sample fat, lean, and bone content as measures of beef edible yield. These objective measures of carcass quality were developed from about 1925-1944. They have been widely adopted.

Breeding Research

Beef Cattle—Feed costs of producing beef may be reduced by selective breeding: There is a high, positive correlation between rate and feed efficiency of feedlot gain. Breeders who select for feedlot gain among steers of the same weight may expect about as much genetic improvement in both gain and feeding efficiency, by using the sire and siblings of fast-growing progeny as by selecting for both. Thus they may avoid the labor and cost of measuring individual

feed intake. Beef cattle breeding research at Beltsville and Miles City, Montana, established the high heritability of feedlot gain and feed efficiency of beef cattle (Knapp and Nordskog, 1946). This discovery, confirmed by many other researches, has led to the wide use of performance-tested sires and of sires of several large, fast-growing, exotic-sire breeds, e.g. Charolais, Simmenthal, and Chianina. The ultimate result has been the marketing of younger cattle at preferred weights and many millions of dollars savings in fixed and variable costs of beef production.

One goal in improving reproductive efficiency of livestock is to determine the heritability of twinning in cattle and to incorporate this improvement into commercial herds. Production research such as this is carried out at the ARS Roman L. Hruska U.S. Meat Animal Research Laboratory at Clay Center, Nebraska.

Dairy Cattle—Secretary Wallace, in his 1936 annual report, disclosed evidence that continued use, generation after generation, of dairy sires proved by their daughters' first lactation records was likely to yield subsequent daughters with production greater than their dams. Young bulls produced in the Bureau of Dairy Industry herd, Huntley, MT, were proven in local cooperators' herds. Forty-nine such Holstein bulls sired 579 daughters whose average production was greater than that of their dams by 1,452 lb. of milk and 57 lb. of butterfat. Only 5 of the 49 bulls failed to increase daughters' production.

There is a substantial cost in sire-proving. Length of generation interval, about 5 years, results in the discard of many sires before proof is complete.

Continuous use of superior proved sires has been demonstrated to result in continuous improvement in milk and butterfat production. M. H. Fohrman reported in the 1947 *Yearbook of Agriculture* that continuous use of proved sires in the Beltsville Holstein herd resulted in an increase of milk per cow from 18,936 lb. in 1926 to 22,114 lb. in 1945, and in butterfat from 672 lb. in 1926 to 856 lb. in 1945. In the Jersey herd at Beltsville the average milk production increased from 11,567 lb. in 1926, to 14,253 lb. in 1945, and the butterfat increased from 632 lb. per cow in 1926, to 812 lb. per cow in 1945.

Dairy Herd Improvement—The number of cows in the Dairy Herd Improvement Association (DHIA) increased from about 350,000 in 1925 to about one million in 1948. Milk production of DHIA cows increased from about 3,150 kg in 1925 to 4,000 kg in 1948. The average production of all USA milk cows during this period increased from about 1,950 kg to 2,350 kg.

Poultry Breeding—Charles W. Knox, Joseph P. Quinn, and Albert B. Godfrey (1943) compared crossbred and standardbred progenies of Rhode Island Red, White Wyandotte, and Light Sussex chickens. Crossbred mortality was sub-

stantially and significantly less, by 6 to 15 percent.

Selective breeding of a small white turkey was initiated about 1935. The project was launched following a survey conducted by the Chainstore Association which found a need for turkeys weighing 8 to 10 lb. for family use. Turkeys of several varieties—White, Bronze, Black, and Wild—were crossbred. Selective matings followed with selection for broad breast, small size, white color, higher egg production, hatchability, and viability (Marsden and Martin, 1944).

Within a research period of less than 12 years the stated objectives had been achieved by Stanley J. Marsden who knew turkeys—their habits, their husbandry, and their feed requirements. It has not yet been demonstrated that genetic engineering is capable of reaching comparable objectives more quickly—and surely not at less cost.

The Beltsville Small White Turkey (BSW) was widely accepted by growers and consumers. The number of small turkeys produced, not all of them BSW, had reached more than 15 million by 1974. Popularity has been restricted by two factors: 1) The cost of processing a small turkey is about the same as that of a large one; ergo, processing cost per pound of BSW is twice that of large turkeys; 2) preparation, carving, and serving costs are about the same for a big turkey as for a small one. Restaurants, hotels, and other institutional users prefer big turkeys.

Sheep—J. M. Cooper (1939) reported that 400 years of natural selection and culling had resulted in adapting Navajo sheep to the scant forage and rigorous climate of the semiarid tribal area. Navajo sheep produce light-shrinking fleeces of long, strong wool fibers with wave rather than crimp, suitable for weaving good quality Navajo rugs. Research with the Ft. Wingate, NM, station flock of Navajo sheep was designed to improve wool yield of uniform quality acceptable to the Navajo people and their weavers. Wool quality and yield were improved by selective breeding; however, even with suitable wool, only the most skilled Navajo weavers could produce fine quality rugs that would bring a highly profitable price.

Basic research on inbreeding, crossbreeding, heritability, maternal, and environmental effects on lamb and wool production and fecundity was carried on at the Western Sheep Breeding Laboratory. It was funded under the Bankhead-Jones authority in cooperation with 11 contiguous Western States and South Dakota. Research at the station had produced the Columbia and Targhee breeds from crossbred bases. The Columbia flock produced more lamb and wool in an eight year test than contemporary flocks of 4 other breeds.

Genetic improvement to be expected in traits of economic importance depends on (a) the proportion of progeny selected for breeding (selection pressure); (b) the interval between successive generations; and (c) the heritability of the selected traits. Heritability may be expressed in a scale of 0-1.00. At any given combination of selection pressure and generation interval, the higher the trait heritability, the more rapid is genetic progress likely to be achieved. L. N. Hazel and C. E. Terrill (1946) determined heritabilities for several traits, using data gathered at the Western Sheep Breeding Laboratory. These were weaning weight 0.30+0.04; staple length 0.40+0.05; face covering 0.56+0.05; and neck folds 0.39+0.05.

Swine Breeding—In 1934, W. A. Craft was sent to Denmark by the USDA, where he selected and brought back to the United States, via quarantine in the Virgin Islands, 8 males and 16 females of Danish Landrace swine. The Danish Landrace had an outstanding reputation for quality of bacon produced, a lean kind preferred in British markets. These Landrace were then used in Animal Husbandry herds at Beltsville and at experiment stations in Iowa, Minnesota, and Maryland, in purebred and crossbred matings, and in selected advanced generations to establish new lines of superior meat types.

Research on the effects of selective breeding for increased rate of gain, feed efficiency, and carcass quality was greatly accelerated by the establishment of a Regional Swine Breeding Laboratory and by the acquisition of the Danish Landrace breeding stock.

The Regional Swine Breeding Laboratory was established with headquarters at the Iowa Experiment Station, Ames. About 1937, Dr. Craft was appointed to coordinate the research of 12 stations (Iowa, Nebraska, South Dakota, Minnesota, Wisconsin, Illinois, Indiana, Ohio, Michigan, Missouri, Kansas, and Oklahoma) and the Animal Husbandry Division on selective breeding, wider inbreeding, crossbreeding, outbreeding, and combinations of these systems. Funds appropriated to the USDA under authority of the Bankhead-Jones Act were provided to supplement State and other funds. Swine breeding research at Beltsville was closely coordinated with that of the Regional Swine Breeding Laboratory.

M. L. Baker, L. N. Hazel, and C. F. Reinmiller (1943) put forth an hypothesis that an individual's own heredity plays an increasing role from fertilization until the trait is fully expressed. They found the hypothesis to be tenable for weight and rate of gain of pigs from birth to 112 days of age. They concluded that maternal, litter, and individual environment account for most of the variation in weaning weight. Therefore, selection of boar pigs for breeding should be made at 112 days when heredity is more fully expressed. This conclusion was confirmed by Dickerson and Hazel who (1944) recommended that 8 to 10 times as many boars and 3 times as many gills be retained to about 112 days of age before final selection for breeding.

Feeding and Nutrition: Beef Cattle

Wintering Range Cattle—W. H. Black and his colleagues, in USDA *Technical Bulletin* 603, 1938, reported that brood cows spent three out of five winters on the range at Miles City, MT. During severe winters brood cows were each fed 1 pound of cotton-seed cake and 10 pounds of hay per day. Weight records kept of the steers, as calves and yearlings, wintered at high, medium, and low planes of nutrition, reached 33-month weights of 1,068, 1,036, and 1,031 pounds, respectively. The steers that were wintered at low and medium planes of nutrition gained weight faster on the range in summer and fall than the steers that were wintered at a high plane of nutrition.

Phosphorus Deficiency—Soils in many areas of the world, e.g., central Brazil and the Texas Gulf coast, are deficient in available phosphorous. Forage grown on such soils is likely to contain too little phosphorous to safisfy the requirements of cattle, especially requirements for reproduction. P-deficient cattle develop abnormal appetites, e.g. they chew bones; they become "creepy" (crawl on their knees); their reproductive rate is low.

W. H. Black and his colleagues found in 1943 that most forage samples from 15 South Texas counties contained less than 0.13 percent phosphorous, the estimated requirement. Test control cows grazing native forage had a 64 percent calf crop compared to 85 percent for cows given a disodium phosphate supplement. The weaning weights for the control group averaged 190 kg; the phosphorous supplement group 230 kg. Three lactating control cows were "creepy".

The Animal Husbandry Division, the Texas Agricultural Experiment Station, and the King Ranch conducted cooperative research on this problem for more than 10 years, beginning in 1937. The research demonstrated that while the forage content of P could be increased by the use of phosphate fertilizer, equivalent benefits in calf crop and growth rate were achieved by adding bone meal supplements to the salt or disodium phosphate to the drinking water supplies (USDA *Technical Bulletins* 865 and 981).

Vitamin A Deficiency—Deficiency of vitamin A in cattle results in night blindness and anasarca (a massive edematous condition). Russell E. Davis and L. L. Madsen (1943) reported a study of plasma carotene levels and reproductive performance for pasture born Hereford and Shorthorns that had been weaned in the fall, then placed on an A-deficient diet and bred 6 months later. As heifers showed symptoms of night blindness or other symptoms of A-deficiency during the 6 month depletion period, they were given carotene supplements of 30, 45, 60, or 120 micrograms of carotene per day. Calves were born blind or dead at the lowest level of carotene intake, and normal at 60 microgram levels. Plasma carotene of the heifers receiving 60 micrograms carotene per day was 81 micrograms per milliliter compared with 813 micrograms per milliliter for pastured controls.

Dairy Nutrition

Forage Feeding—Forage is the most economical feed source for dairy calves from weaning to puberty. Forage of high quality—high in protein and vitamin A—is an important part of the lactating cow's ration. Because of its bulk, forage cannot supply all the nutrients required to sustain peak milk production of cows with high genetic capacity for milk production. Indeed, as D. Stuart reported in the 1927 *Yearbook of Agriculture,* during the first month post partum, cows producing 40 lb. of milk per day do not eat enough to meet energy requirements.

Vitamin A—Meigs and H. T. Converse (1933) reported results of 10 years of Beltsville experimental feeding of dairy cows on grain and hay without pasture. Cows fed alfalfa hay reproduced normally. Those fed No. 5 timothy dropped fewer calves, some weak, blind, or dead, indicative of vitamin A deficiency in feed. Many calves fed only skimmed milk and low vitamin A roughage died before they reached 6 months of age.

Energy Requirements—In 1925 E. B. Meigs and his colleagues at Beltsville initiated basic research on the energy

requirements of dairy cows (Meigs and Converse, 1925). Meigs was critical of Armsby's estimates of energy requirements for maintenance of dairy cows, arguing that they did not give full consideration to muscular activity, which must increase with increasing feed intake. Meigs and Converse reported empirical data for maintenance energy requirements both of cows allowed liberal rations and of cows limited in feed intake. At both levels Meigs' data exceeded Armsby's published estimates by about 18 percent.

Cary (1939) reported that a 1,000-pound cow at rest required about 11 thousand calories metabolizable energy (MCal ME) for maintenance according to the Haecker standard. Cary estimated that the same cow "working in the dairy" required about 13.0 MCalME. Cary stated that digestible energy requirement for milk production was 1.72 times the gross energy of milk. Calculated efficiency of use of ME for milk production was estimated to be 63 to 68 percent. We shall note later in this review that Cary's lower estimate is still valid.

Poultry Nutrition

H. W. Titus, M. A. Jull, and W. A. Hendricks (1934) reported that the W. J. Spillman curve of diminishing increments fits the relations between weight for age of growing chickens and cumulative feed consumption with a high degree of accuracy. They reported an equation derived by Hendricks from the Spillman equation for the curve of diminishing increments which may be used to describe feed efficiency: $E=c-kW$, in which E is gain in liveweight per unit weight of feed consumed, i.e. feed efficiency; c is the maximum efficiency of feed utilization for growth; k measures the rate of decrease in feed efficiency as liveweight increases; W is the weight at which feed efficiency is being measured. Successive weights and cumulative feed consumption data are used to calculate efficiency.

The basic research of Titus and Hendricks, relating the growth of chickens to feed consumption and both to Spillman's law of diminishing returns, constitutes a lasting contribution to the science of nutrition. They reported that empirical data resulting from feeding growing chickens different proportions of feed of unlimited consumption were described by fitting the Spillman (1934) equation to the cumulative weight and feed consumption data for chickens on each plane of nutrition.

Feed intake of seven experimental groups were respectively: ad lib. 90, 75, 64, 51, 38, and 25 percent. Mortality in the three lowest intake groups increased in inverse proportion to intake, more so in males than in females. In the 25 percent intake groups, mortality to 36 weeks was 90 percent for males and 65 percent for females. J. C. Fritz, W. H. Burrows, and Titus (1936) reported that cracked corn was poorly digested by gizzardectomized fowl (34 percent) compared to normal controls (86 percent). Ground corn was digested about as well by gizzarectomized (84 percent) as by normal controls (95 percent). Fritz (1937) found that feeding grit increased the digestibility of inorganic matter by normal chickens by 3 percent, and of crude fiber by 15 percent, compared to controls not fed grit.

Titus (1932) described a deforming leg weakness in chickens, perosis, as a deformity of nutritional origin in growing chickens. This discovery was confirmed and extended at other laboratories and resulted in correction of dietary magnesium deficencies in poultry diets.

T. C. Byerly, Titus, and Ellis (1933) reported that eggs from hens fed diets with cottonseed meal or soybean meal as the only protein concentrate were about 60 percent hatchable. Similar hens fed diets containing animal protein concentrates produced eggs with about 70 percent average hatchability. The authors concluded that vegetable concentrates lacked some vitamin which was present in animal protein concentrates.

H. R. Bird and J. A. Marvel (1943) reported that floor-housed hens fed corn-soybean meal diets produced eggs of higher hatchability than caged hens fed the same diet. Bird, in a later study with M. Rubin, D. Whitson, and S. K. Haynes, (1946) reported that hens fed a diet containing 10 percent sardine meal as protein concentrate (positive control) produced eggs 80 percent of which were hatchable and chicks with 6 percent post-hatching mortality; hens receiving soybean meal instead of the sardine meal (negative control) produced eggs 66 percent of which were hatchable and chicks with 29 percent post-hatching mortality. Hens fed the negative control diet supplemented with 5 percent of cow manure produced eggs 82 percent of which were hatchable and chicks with 9 percent post-hatching mortality.

Rubin, Bird, and Rothchild (1946) reported that eggs of normal hatchability and chicks of normal viability were produced by hens fed urine-free feces from colostomy hens as a supplement to corn-soybean meal diets. Hen feces evidently contain the same factor as cow manure and animal protein concentrates, and coprophagy obviously is a source of vitamin B12 for floor-housed hens.

E. L. Rickes and colleagues (1948) reported the isolation of crystalline vitamin B12. They reported vitamin B12 yielded identical growth response in *Lactobacillus lacto* as the precipitate from papain digest of cow manure reported by Rubin and his colleagues (1946) for hens fed a diet containing a high level of soybean oil meal.

R. J. Lillie, Olsen, and Bird (1949) reported that hatchability increased when crystalline vitamin B12 was injected into incubating eggs which had been laid by hens fed a diet deficient in vitamin B12; (controls had 44 percent hatchability, and B12 injected eggs 71 percent).

The identification of the factor from animal protein concentrates (APF), the cow manure factor, and the hen feces factor as vitamin B12 was complete. Establishment of the identity of and necessity for vitamin B12 was soon followed by availability of synthetic vitamin B12 for feed use. The final result of this 20-year series of research has been the establishment of soybean meal supplemented by vitamin B12 as the principal protein concentrate used in chicken diets, starter diets, as well as in grower and layer diets. The hatchability of hens' eggs averages now about 85 percent, compared with about 65 percent in 1935.

Swine Nutrition

According to W. Jackson, in the 1928 *Yearbook of Agriculture,* farmers in Iowa and Illinois found that 64 percent of their cost of hog production was feed cost. An important factor contributing to feed cost was that of mortality of pigs farrowed, since cost of sow feed for producing them and their own feed consumed prior to death was absorbed by the survivors. Of every thousand pigs farrowed, 340 were lost.

N. R. Ellis and J. H. Zeller (1934) reported that limiting pigs to one-half or three-fourths of ad lib intake decreased the amount of feed required to produce a pound of gain. Feed restriction resulted in reduction of carcass fat, increase in percent of lean, and softer pork. Pigs weighing about 62 pounds each were fed daily rations at 4 percent, 3 percent and 2 percent of their live weight, to final weights of about 205 lbs. The time periods required to reach final weight were 113 days, 151 days, and 229 days; the feed intake per pound of gain was 3.80, 3.54, and 3.50 pounds; the fat in the total edible portion of the carcasses, 45.5 percent, 41.7 percent, and 34.7 percent.

Physiology of Reproduction

Dairy Cattle—W. W. Swett, C. A. Matthews, and M. H. Fohrman of the Bureau of Animal Industry at Beltsville, described and illustrated the first two-celled fertilized ovum ever recovered from the fallopian tube of a cow. This accomplishment was an important contribution to knowledge of normal embryonic development in cattle, essential as a baseline for solving problems of reproductive failure.

Swett, along with his colleagues, Fohrman and Matthews, also contributed basic information on the structure and blood supply of the cow's udder. Fore- and hindquarter udders most usually are separated. Each teat has a single duct leading from a "milk cistern" into which several milk ducts carry milk from the secreting cells. Four Holstein cows had a total udder capacity varying from 12 to 20 liters each. An arterial system for each udder half is based on a pudic artery which divides into a cranial and caudal mammary artery supplying the fore- and hindquarter pudic veins parallel the arterial system.

Poultry—Basic research results on maturation of the hen's ovum and its ovulation conducted at Beltsville have provided information essential for the environmental and physiological management of egg production and reproduction in domestic fowls.

M. W. Olsen (1942) reported the maturation of the hen's ovum. The first polar body is extruded before ovulation. The spindle for the second maturation division then forms and ovulation occurs. Fifteen minutes later, fertilization occurs in the infundibulum. The second polar body is extruded following sperm penetration of the ovum. Male and female pronuclei fuse. First cleavage occurs 5 hours later.

Richard M. Fraps and A. Dury (1948) reported that lutenizing hormone (LH) induced ovulation in response to an injected dose of 0.05 mg. Follicle stimulation hormone (FSH) required a dose of 1.5 mg, a quantity large enough to carry LH contamination sufficient to account for ovulation induction. Fraps and G. M. Riley (1942) reported that intravenous injection of LH following several days pretreatment with injections of pregnant mare serum (PMS) resulted in multiple ovulations, seven in one hour. Fraps, Olsen, and B. H. Neher (1942) reported that injection of four rat units of LH

induced premature ovulation, 10-11 hours later, of single normal follicles.

Rothchild (1946) reported that the pituitary hormone for ovulation (LH) is released 5 to 6 hours before ovulation. He and Fraps (1949, 1949a) reported experiments using hypophysectomized and normal hens to elucidate the sequential action of progesterone which acts on the pituitary to release LH, the ovulation hormone. They reported that progesterone injected 36 hours before expected ovulation inhibited or prevented ovulation.

W. H. Burrows and Quinn at Beltsville developed a method for manually stimulating ejaculation in roosters, aiding in artificial insemination of poultry. In 1939 they described a method of semen collection from roosters and toms and the use of such semen for insemination of hens. This method was adopted quickly by poultry breeders, especially for heavy turkeys. The method consists of manual massage of the abdominal, a pericloacal region, followed by manual pressure to evert the genital eminences and squeeze out the semen from the bulbous terminal portions of the exposed ducts. Semen is collected in a suitable beaker held below the protruded genitalia. As originally applied, undiluted semen was injected by syringe into the oviduct of the recipient hen, everted by manual pericloacal pressure by a second operator.

Sheep—R. T. Clark (1934) reported that flushing (supplementary feeding before breeding to induce weight gain of females) increased the rate of ovulation in ewes in poor condition but not in those in good condition. Clark described fertilization and cleavage. Male and female pronuclei fused about 30 hours post coitum, and first cleavage occurred 6 to 7 hours post fused. "The two cell stages presented in this study are, as far as is known, the first that have been recovered from the sheep."

Dairy Products

Speaking on behalf of the newly established Bureau of Dairy Industry (BDI), L. A. Rogers, who was in charge of the BDI laboratories, stressed the importance of basic research.

In the 1926 *Yearbook of Agriculture*, Rogers reported the potential availability of more than 2 billion pounds of nonfat milk solids, chiefly protein and lactose, for food or industrial use. Most of these solids were used for pig and poultry feeding. Poultrymen were feeding large quantities of barreled, semisolid buttermilk, which they believed would protect their growing chickens against coccidiosis. Rogers stated: "Not withstanding the inefficiency of the method, it will probably be necessary for many years to come to utilize a large portion of dairy byproducts by feeding them to animals." (Rogers, 1926, p.297.)

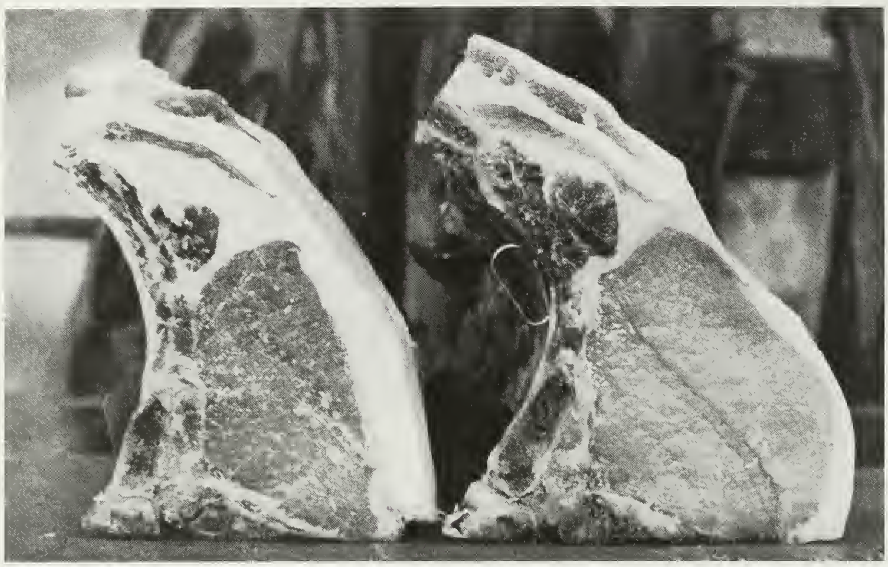
The chronic whey-utilization problem in 1948 amounted to about 9 million pounds. Cheese whey in the United States contains 6.9 percent solids; more than 280 million kg, of this amount about 12 million kg is fat, 20 million kg protein, 200 million kg lactose, and about 240 kg riboflavin. Riboflavin content can be upgraded by fermentation with *Clostridium acetobutylicum* to form a useful riboflavin concentrate. Whey protein is of excellent quality, suitable for extended food use. Lactose can be separated and fermented to make ethyl alcohol.

Meat Quality Evaluation

A cooperative project in which 30 State experiment stations and the National Livestock and Meat Board cooperated with the Animal Husbandry Division was initiated about 1925. Meat specialists Orval Hankins of the Animal Husbandry Division, Kenneth Warner of the USDA Extension Service, and chemists Paul Howe, Ned Ellis, and Nick Barbella were principal USDA participants. Warner, in cooperation with meats specialist Bratzler of the Michigan station, invented a mechanical device for objective measurement of tenderness, which is negatively correlated with resistance to shear force. Warner (1928) described the research program: Tenderness and palatability of samples from a thousand steer carcasses were to be determined; and eleven hundred hog carcasses were to be used in soft pork and pork curing studies. In 1928 Warner stated that parts of the animal that were most exercised yield tough meat, while the less exercised muscles of loin yield tender meat. The statement was reasonable but unsubstantiated.

Barbella, B. Tanner, and T. C. Johnson (1939) reported that desirability of flavor and the amount of meat juice increased as percentage of fat in the samples increased from 7.5 percent to 57.4 percent. Variance analysis of flavor test data indicated that fat contributed 41 percent of the variance, breeding accounted for 24 percent, age of the animal 26 percent, and sex 6 percent. Hankins and Ellis (1934) reported a correlation ($r = +0.84$) between average backfat thickness measured at five points and fat in the total edible. Backfat thickness, easily measured, has become a stan-

dard measure of fatness used in breeding improvement through sibling and progeny tests.



Researchers have improved the ratio of fat to lean and have produced meatier animals through genetic studies.

Orval Hankins, B. Knapp, Jr., and R. W. Phillips (1943) reported the following correlations between separable fat, lean, and bone in 9-10-11 rib cut and separable fat, lean, and bone in total carcass of beef and dual purpose Shorthorn steers: fat, r = + 0.93; lean, r = + 0.90; bone, r = + 0.80. Values for fat and lean led to use of 9-10-11 rib samples of cattle carcasses and of lamb rib cut as indicators of whole carcass composition.

Horses

J. O. Williams reported in 1927 that an 8-horse team in 1 day could plow 8.5 acres, disc 40 acres, or harrow 80 acres. In the 1936 *Yearbook of Agriculture*, Williams and W. Jackson reported data, 1919-1926, on the results of endurance tests for light horses, conducted to measure for cavalry fitness. The tests took 5 days and covered 300 miles. Each horse carried 21 to 25 percent of its own weight and proceeded at a sustained rate of 5.3 to 6.6 miles per hour for about 10 hours per day. Of those horses entered in the test, 60 percent of the Arabians, 45 percent of the Thoroughbreds, 43 percent of the American Saddlers, and 44 percent of the Morgans finished.

World War II and the post-war UNRRA Livestock Rehabilitation Program necessitated the transport of large numbers of horses and feed. I. P. Earle and colleagues (1945) reported the development of a forage press-cake for horses, in order to minimize shipping volume of feed. Earle estimated that about 0.43 percent of body weight per day was the minimum forage dry matter intake to maintain health in horses.

Fur Animals

Fur animals, wild and farmed, were a responsibility of the USDA Bureau of Biological Survey until 1940, when responsibility was transferred to the Department of the Interior. Some 10 years later, responsibility for farm-raised fur animals was returned to the USDA and placed in the Animal Husbandry Division. In 1939, Charles Kellogg, Bureau of Biological Survey, stated in an article in the *Yearbook of Agriculture* that mink need raw meat in their diet; the meat may come from horses, cows, or sheep. Chicken heads may also be used. About 1948 the use of diethylstilbestrol (DES) for growing and fattening chickens became widespread. Mink producers alleged reproductive failure in their breeding herds, caused by feeding, on the advice of USDA, chicken heads containing DES. They sought relief by private bills introduced in Congress. The Congress shifted the claims to the Court of Claims which, after review, rejected them in 1962. In the meantime, FDA withdrew approval for use of DES in chickens, after finding residues in edible portions of treated chickens.

PERIOD THREE: 1949-1972
EXPLOITATION

During this period of exploitation, livestock research was expanded by the establishment of regional projects in cooperation with State experiment stations—in dairy, beef cattle, and poultry breeding in the Southern Region; in dairy and

poultry breeding and poultry products in the North Carolina Region; and in beef cattle breeding in the Western Region. Funds appropriated under authorization of the Research and Marketing Act of 1946 provided partial funding for these projects. Transfer from the Department of Defense to the USDA of the remount stations of Front Royal, VA, Fort Reno, OK, and Fort Crawford, NE, provided added facilities.

Later in the period, poultry laboratories were established at Bridgeville, DE, and at the Mississippi State University; and the Meat Animal Research Laboratory was established at Clay Center, NE. Beef cattle research was terminated at Front Royal and at Fort Robinson, NE.

After the BAI and the BDI ceased as entities, research in animal, dairy, and poultry husbandry continued in Animal Husbandry and Dairy branches, later consolidated into an Animal Husbandry Division. Meat and dairy products research was transferred to the Eastern and Western Utilization Laboratories. Crossbreeding and hybridization became the dominant breeding systems for production of beef, swine, sheep, broilers, and laying hens. The use of sub-therapeutic levels of antibiotics in feed for growing pigs and chickens to increase rate of growth and feed efficiency became general. Use of diethylstilbestrol (DES) to increase feed efficiency and rate of gain in beef cattle was widely adopted, but finally, in 1976, prohibited.

Artificial insemination with semen from proven superior sires contributed to the steady increase in milk production per cow, which almost doubled during the period.

Systematic, selective breeding of meat-type hogs reduced lard yield from about 32.8 lb. per hog slaughtered in 1955, to 16.2 lb. in 1974. The yield of the lean cuts increased from about 70 lb. per carcass to about 90 lb. Toward the end of the period a vaccine immunizing chickens against Marek's disease—a neoplastic disease—was developed and licensed in 1973. Its use was estimated to have reduced the cost of broiler production by 5 cents per pound, and of eggs about 2 cents per dozen. Annual total savings from its use are about $150 million annually.

Organization, Facilities, and Personnel

Following funding authorized by the Research and Marketing Act of 1946, regional projects were established. Regional projects in dairy genetics were cooperative among the Bureau of Dairy Industry and its successor units and the States of the North Central and Southern regions. Milton Fohrman was a USDA participant in the North Central project, and R. E. McDowell in the Southern. Poultry breeding projects in the North Central and in the Southern regions had as USDA coordinator in the North Central projects Don C. Warren, followed by Claude Moore, Stephen King, and V. A. Garwood, and in the Southern projects Carl Hess, Bob Cook, and H. L. Marks.

Beef cattle in the Southern Region had as USDA coordinator C. M. Kincaid. In the Western Region R. T. Clark was a highly dynamic coordinator.

The Army's Remount Service was discontinued, and the Stations at Fort Robinson, NE, Fort Reno, OK, and Front Royal, VA, were transferred to the USDA and assigned to the Animal Husbandry Division. The Fort Robinson and Front Royal Stations were used for beef cattle genetic research, in cooperation with the respective State experiment stations. The Shorthorn breeding herd at Beltsville was transferred to Front Royal. W. H. Black was placed in charge of the Front Royal Station, and R. Davis in charge at Fort Robinson. Research at Fort Reno focused on feeding and management of range beef breeding herds and swine under direction of Dwight Stephens.

Front Royal and Fort Robinson Stations were terminated due to funds restriction; Front Royal was transferred to the National Zoological Park, Washington, DC, for the propagation of large exotic herbivores. The Fort Robinson Station was transferred to the State of Nebraska for wildlife and historical activities, after the USDA acquisition from the Department of Defense of an area more favorable to meat animal research at Clay Center. This Meat Animal Research Center has become a major national meat animal research center.

During the period 1948 to 1972, the Middlebury Horse Farm was transferred to the State of Vermont, and mule research in Tennessee was terminated. The dairy breeding research at Huntley was terminated. The breeding herd was transferred to Logan, UT, where the research was continued. The dairy and beef cattle research at Jeanerette was terminated, as was the U.S. Fur Animal Experiment Station at Saratoga, NY, the Rabbit Station at Fontana, CA, and the Poultry Station at Glendale, AZ.

Following the 1953 demise of the Bureau of Dairy Industry and the Bureau of Animal Industry, research on dairy products, and much of the meat research was transferred to the Eastern Utilization Regional Research Laboratory in Philadelphia. Research on objective measurement of carcass and fresh meat quality continued at Beltsville.

Livestock research, under Bennett T. Simms as Director and T. C. Byerly as assistant, was organized from 1953-1957 into an Animal Disease and Parasite Branch, Howard W. Johnson, Chief; Animal and Poultry Husbandry Research Branch, Ned R. Ellis, Chief; and Dairy Husbandry Research Branch, Ralph E. Hodgson, Chief.

Livestock research was further reorganized in 1957. T. C. Byerly became Deputy Administrator, Agriculture Research Service, and was succeeded in 1962 by Herman A. Rodenhiser, charged with general supervision of farm research, including animal and poultry husbandry, and then was consolidated into a single Animal Husbandry Division, R. E. Hodgson, Director.

The division consisted of six branches—Beef Cattle, E. J. Warwick, Chief; Dairy Cattle, Joseph F. Sykes, Chief; Poultry, Stephen C. King, Chief; Sheep and Fur Animal Research, Clair B. Terrill, Chief; Swine, J. H. Zeller, Chief; and Meat Quality, R. L. Hiner, Chief.

At the end of the period, the divisional branches were carrying on research at these locations: Dairy—Beltsville, Logan, UT, and Lewisburg, TN; beef cattle—Beltsville, Miles City, MT, Fort Reno, OK, Brooksville, FL, and Clay Center, NE; poultry—Beltsville, East Lansing, MI, Athens, GA, Mississippi State and Lafayette, IN; sheep research—Beltsville, Dubois, ID, and Clay Center, NE; swine research—Beltsville and Clay Center, NE; and meat quality—Beltsville and Clay Center.

Highlights

Purified cattle diets in which nonprotein nitrogen compounds were totally substituted for protein were found to support calf growth and adult reproduction. This notable achievement provides a more rigorous standard for evaluating feeds containing many still unidentified constituents.

Development of the meat-type hog is a major achievement of the swine industry, causing an increase in the production of lean pork and a decrease in yield of lard. The contributions of W. A. Craft as director of the Regional Swine Breeding Laboratory, of John Zeller and his colleagues at Beltsville in selective breeding, and of Ralph Durham in establishing the potential for meat-type in all breeds and crosses—all are important.

The economic cost of wintering beef cattle at a maintenance level is much lower than supplementary feeding to assure gain in weight. Winchester and his colleagues at Beltsville demonstrated that such interrupted growth may not increase cumulative feed cost or decrease carcass quality of cattle subsequently fed *ad lib* to market weight. Dwight Stephens and his colleagues at El Reno, OK, demonstrated in a 15 year research comparison that cows wintered on range forage, with a low level of feed concentrate, produced more calves than cows wintered with a high level of concentrate feed supplement.

Parthenogenesis in turkeys, producing the first naturally occurring fatherless individuals in warm-blooded animals, and the first to survive to maturity—whether naturally or experimentally induced—was demonstrated by Marlow Olsen at Beltsville. This is an important contribution to science, demonstrating that reproduction of turkeys can, and does, occur occasionally without fertilization of the eggs by male sperm.

Using turkey herpes virus, Graham Purchase and Walter Okasaki developed a vaccine against Marek's disease of chickens at the Regional Poultry Laboratory, East Lansing, MI. Its application in egg production in 1973 reduced layer mortality and morbidity substantially. It was the first field application of immunization to prevent a cancerous disease.

Crossbred dams are likely to exceed linebred dams in reproductive efficiency. Rotational mating of beef cattle maximizes the percentage of crossbred cows in commercial breeding herds, in comparison with fixed two-breed or three-breed systems (Dickerson, 1973). For swine, a three-specific-breed-cross system is preferable (Tess and others, 1983).

Breeding

Beef Cattle—Genetic gains in the closed Hereford Line One at Miles City, MT, from 1934 to 1959 were reported by J. S. Brinks, R. T. Clark, and N. M. Kieffer. During the period, records through weaning were kept for 2,027 calves,

sired by 33 bulls. Inbreeding in the line increased from 0.7 percent in 1934 to 21.6 percent in 1959. All measurable heritable traits phenotypically decreased as inbreeding increased. Weaning weights of calves were depressed as dams' inbreeding increased.

Genetic gains equalled expectations based on index of trait heritability, selection pressure, and generation interval. Genetic gain in birth weight was 9.7 lb, weaning weight was 30 lb, and in weaning score 6.5 percent. Linebred and crossbred matings among Hereford, Angus, and Charolais cattle and of crossbred males of progenies of these matings and Brown Swiss females were made at Miles City. Progenies of the Brown Swiss cows had heavier birth and weaning weights than progenies of the other matings. Beef breed progenies exceeded Brown Swiss in weanings score.

G. E. Dickerson (1972) summarized benefits and limits of inbreeding and crossbreeding in beef cattle. About 80 lines of beef cattle inbred at Federal and State experiment stations have been discarded for poor performance. Low fecundity of beef cattle limits the proportion of crossbred calves which can be produced in cross-breeding systems of two-specific or three-specific breeds to 54 percent to 84 percent, and of crossbred cows in a three-specific breed system to 64 percent. These facts give advantage to rotational crossbreeding, for only sires need to be purebred, and about 98 percent of calves and cows can be crossbred.

Dairy Cattle—Long-term comparisons of crossbreeding and line breeding in dairy cattle have given mixed results. Viability of crossbred progeny have sometimes, but not always, exceeded the purebreds. Milk production of the crossbred tends to exceed the mean of the two parental lines crossed but seldom exceeds that of Holsteins resulting from multigeneration use of superior proven sires.

Calves from Brown Swiss cows often have higher perinatal mortality, associated with dystocia, than calves from cows of other breeds.

In the North Central dairy breeding project, perinatal and later death losses were 32.7 percent for purebreds compared with 13.4 percent for crossbreds. Milk production for Holstein first lactations averaged 12,900 pounds; Holstein/Guernsey crossbreds, 9,700 pounds; Guernsey/Holstein crossbreds, 8,100 pounds; and Guernsey purebreds, 5,100 pounds (F. N. Dickerson and R. W. Touchberry, 1961).

Results of crossbreeding experiments begun at Beltsville in 1939 were summarized by M. H. Fohrman and others in USDA *Technical Bulletin* 1974. Proved sires of Holstein, Jersey, and Red Danish breeds were used. Foundation cows of Holstein, Jersey, Guernsey, and Red Danish breeds had average first-year lactation records of 10,540 lb. milk and 455 lb. butterfat (BF). Average production of first-cross cows was 13,039 lb. milk and 585 lb. BF, and of three-breed crosses, 13,361 lb. milk and 588 lb. BF. However, in comparison of Holstein dams' production with that of the crossbred daughters sired by Jersey bulls, the dams' milk production exceeded that of their crossbred daughters by about 800 lb. of milk, while daughters' BF production exceeded the dams' by about 50 lb. Comparison of Holstein dams and crossbred daughters sired by Red Danish bulls showed that the dams' milk production exceeded daughters by about 650 lb.; the daughters' BF production exceeded that of their dams by 45 lb.

Crossbreeding among the Red Sindhi (*Bos indicus*) dairy breed, Holsteins, and Brown Swiss gave mixed results. In the Southern Regional Dairy Breeding Project, the stations of Georgia and Louisiana cooperated with Beltsville in crossbreeding Holsteins, Brown Swiss, and Red Sindhis; there was greater viability and greater adaptability among these crossbreds than among the *B. taurus* dairy breeds. Losses from stillbirths and abortions for Holsteins in the Louisiana project were 20 percent, contrasted with only 9 percent for calves from crossbred dams. Crossbreds with as little as 25 percent Sindhi genes showed greater adaptability than the European breeds. However, crossbreds were generally inferior in milk production to the Holsteins. Crossbreds averaged 1,000 lb. of milk and 70 lb. BF less than their Jersey stable mates (B. T. McDowell and others, 1968; B. F. Hollon and others, 1969).

Production data at Beltsville for 85 two-breed-cross females and 40 three-breed-cross females, in comparison with contemporary purebreds of the parental breeds—Ayrshire, Brown Swiss, and Holstein—were reported by R. E. McDowell and B. T. McDaniel (1968). The Ayrshire/Swiss and the Swiss/Holstein two-breed crossbreds averaged 8 percent to 10 percent above the parental breed means for production traits, but the Ayrshire/Swiss crossbreds showed no such heterosis. The three-breed crosses produced slightly less milk but more butterfat and had higher feed efficiency than the Holsteins. Calves from Brown Swiss cows and from Swiss cross-matings with the other two breeds had higher perinatal mortality than calves from Holsteins, Ayrshires, and cows produced by crosses of Ayrshires and Holsteins. Frequency of dystocia was principally responsible for the difference.

McDowell and McDaniel suggested that the best course for dairy farmers to follow was to breed each cow to the best sire available.

Poultry—The Chicken-of-Tomorrow Program was organized by H. C. Pierce, poultry expert of the A&P Food Stores, and it was sponsored by the A&P Stores. A committee was formed including representatives of 10 poultry organizations, 2 poultry magazines, and the USDA extension, research, and marketing agencies. Program objectives were to identify and recognize genetic lines and crosses yielding broilers outstanding in rate of gain, fast feathering, feed efficiency, viability, and breast fleshing. National contests were held in Delaware in 1948 and in Arkansas in 1951. Both contests were won by progeny of Vantress White Cornish males crossed with New Hampshire females. The winning entry had an average 12-week bodyweight of 4.27 lb., and a feed/lb/gain of 2.89. They were off-white in color and superior in breast fleshing. Second place in 1948 went to Arbor Acres White Rocks, a strain that was dominant white and yielded off-white, fast-gaining progeny. In 1951 second place went to Nichols' New Hampshire, also a fast-gaining strain (H. L. Shrader, 1952).

Impact of the program was extensive and immediate. Broiler color changed from traditionally preferred barred feathers to white or light-colored, which had no obviously colored pinfeathers when dressed. Dominant white or light-colored males were generally adopted. Improvement in genetic capacity for rapid growth and in nutrition have yielded broilers reaching weights and feed efficiencies much greater than those of the 1951 winning entry.

Genetic environment interaction for poultry was determined for 10 genetic stocks fed at 2 protein levels by 9 participating stations over 2 years in the Southern poultry breeding regional project. Location by year accounted for a large percentage of the explained interactions; genetic and dietary differences among the 10 genetic stocks accounted for a smaller portion of the observed variation in production than environmental variation among the 9 locations in the 2 years of observation (H. L. Marks and others, 1969).

Swine—Data for 4,669 pig litters from 40 inbred lines, farrowed at 6 of the participating State experiment stations in the Regional Swine Breeding Laboratory were reviewed by W. A. Craft (1953). The average generation interval was 1.35 years; 8 percent of the males and 33 percent of the female progeny were saved for breeding. Selection for litter size was automatic; more pigs were available for selection from large litters than small ones, so more were selected. In 13 years, average inbreeding had increased 33 percent and the number of pigs weaned had decreased by 1.5 per litter.

In line cross progenies, heterosis was proportional to genetic difference between the lines. Three-line cross progeny excelled two-line. Crossbred, including incrossbred, progenies excelled stocks. Heritability, reported from Iowa studies, was as follows: lean cuts, 0.29; fat cuts, 0.52; and thickness of back fat, 0.51. The ideal market hog has about 100 kg liveweight, has 30 to 31 inch carcass length, 1.5 to 1.7 inch backfat, yields 50 percent of liveweight in five primal cuts. Of 100 inbred lines started by the Regional Swine Breeding Laboratory participants, 57 were discarded for poor performance.

Pork producers have increased the amount of pork produced per sow farrowing from about 400 kg in 1955 to 600 kg in 1981. Lard production declined from about 100 kg per sow farrowing in 1955 to about 35 kg in 1981.

Cooperative action demonstrated the application of a simple method, developed by Lanoy Hazel at the Iowa Experiment Station, for measuring backfat in breeding swine (inserting a depth gauge through a small incision) as a guide to selective breeding for reducing fatness of genetic origin. R. M. Durham demonstrated the technique in 29 purebred herds, 1,100 animals in all, in Illinois, Indiana, Wisconsin, Ohio, and Pennsylvania. This program demonstrated the means and gave impetus to the improvement of meat type in all swine breeds through selective breeding (R. M. Durham and J. H. Zeller, 1955).

Nutrition

Cattle—In 1948, in cooperation with the Oklahoma Agriculture Experiment Station, a cow-lifetime study of the effect of winter plane of nutrition on calf production was initiated at Fort Reno. Cows grazed the range during spring, summer, and fall without feed concentrate supplements. Thirty heifers were assigned feed supplements to their winter range grazing at one of three planes: 1) 1.25 lb. cottonseed meal (CSm) per head per day; 2) 2.5 lb. CSm per head per day; and 3) 2.5 lb. CSm + 2.5 lb. oats per head per day. After 13 years on their regimens, the cumulative calf production, in pounds, of each group, and the cow cost per hundredweight of weanling calf produced were as follows: 1) low plane, 16,290 lb. and $7.62; 2) moderate plane, 11,245 lb. and $10.89; and 3) high plane 5,223 lb. and $14.39.

Higher winter feed planes shortened the productive lives of these cows (Oklahoma Agriculture Experiment Station MP 67, 1962).

In Beltsville, R. R. Oltjen and his colleagues completely substituted nonprotein nitrogen (NPN) for protein in purified diets for cattle. Growth, feed efficiency, and nitrogen retention of young cattle were reduced by about 35 percent as compared with similar cattle fed diets containing adequate amounts of protein. Reproduction on such purified diets has occurred; free blood plasma concentration of essential amino acids is depressed; glycine and serine concentrations are increased (R. R. Oltjen, J. Bond, and C. V. Richardson, 1969).

This is a notable achievement, confirming recent research in Finland. It provides a base for comparison of natural diets containing many still unknown constituents with purified diets consisting of known constituents. Such comparisons and new knowledge on beneficial or deleterious effects of these now unevaluated constituents will be facilitated.

During estrus periods, nonpregnant (open) feedlot heifers interrupt gain. To suppress estrus, heifers were injected with hormonal compounds containing 650 mg progestogin (dihydroxyprogesterone acetiphenomide) (Squibb). A second 2,500 mg injection was administered 28 days later. Heifers were tested for estrus by vasectomized bulls. No heifers displayed estrus after the second injection. Progestogin treatment increased feed efficiency of heifers about 10 percent (P. A. Putnam, Oltjen, and Bond, 1969).

Whether interrupted growth or continuous growth of beef calves to target weight is the more economical has been a matter of disagreement, though it is well established that cattle fed a maintenance diet during the winter gain faster on pasture or range the following summer than do their contemporaries fed *ad lib* during the winter. To resolve this disagreement, Clarence Winchester and his colleagues, Hendricks, Ellis, and Howe used identical twin calves in three successive experiments in comparisons of digestible energy (DE) intake of calves from weaning to prime finish. Calves restricted for 6-month periods to about 50 percent of their twins' liberal feed intake and then fed *ad lib* to prime required about 12 megacalories of DE per pound of gain for the entire period. The continuously growing twins reached target weight and finished sooner than their "interrupted growth" twins. The greater dollar cost of winter feed to maintain continuous growth made this system less economical in many, but probably not all, production systems.

Rearing replacement dairy stock depends largely on the feeding of nonfat milk solids, basically skim milk, to calves for the first several months post partum, with a shift to harvested forage or pasture as seasonably available. The vitamin A content of forage, or vitamin A as a supplement, has been found to be of critical importance. Vitamin A-depleted calves required supplements of 50,000 International Units of vitamin A daily during repletion to reach blood levels of vitamin A equal to those of pasture-raised suckled contemporaries (H. T. Converse and E. B. Meigs, 1939).

Growing heifers fed either high quality alfalfa hay or wilted silage (haylage) had equivalent rates of gain from 5 to 19 months of age, 0.88 pounds per head per day and 0.87 pounds per head per day, respectively. Heifers fed fresh-cut silage, however, gained only 0.76 pounds per head per day because of lower drymatter intake (J. W. Thomas, L. A. Moore, and J. F. Sykes, 1961).

Digestion in the rumen is accomplished by enzymes produced by obligate anaerobic bacteria. Numbers and proportions of different groups of bacilli in the rumen vary with the nature of the diet. Total numbers were estimated at 1.3 billion per milliliter of rumen fluid from steers receiving alfalfa hay, 1.8 billion per milliliter for wheat straw rations, and 6.5 million for concentrated rations. Proportions of cellulolytic bacilli varied from 20.4 percent on wheat straw rations to no isolates on concentrate rations.

Estimated water requirements for thousand-pound dry cows in the winter is about three times the weight of dry matter (DM) intake, at about 5 °C ambient temperature. For thousand-pound beef cows nursing calves, the weight of water required is about 5.4 times the weight of the DM intake, or about 60 liters. At 35 °C ambient temperature the water requirement is about the same as at 20 °C.

Water requirements for dairy cattle at 10 °C to 25 °C ambient temperature are as follows: For growing animals, about 4.3 times the weight of DM intake; for lactating cows, about 4.3 times the weight of DM intake plus 2.6 times the weight of milk produced. DM intake falls sharply at ambient temperatures of 33 °C and higher, while water intake increases.

In a study of forage digestibility, R. E. Ely and colleagues (1953) found that apparent digestibility of lignin in orchard

grass hay declines as maturity of the harvested grass increases, from 4.25 percent to 2.41 percent. Ely and L. A. Moore (1955) found that holocellulose and lignin account for widely varying proportions of the crude fiber in various forages. Holocellulose varies from 39.0 percent of the crude fiber in alfalfa hay to 74.5 percent in wheat straw. Lignin varies from 4.9 percent in young orchard grass to 13.7 percent in soybean hay.

When nitrogen content of DM ingested falls below 0.75 percent, the result is a negative nitrogen balance, a reduced rate and extent of fiber digestion, and the loss of nitrogen from the body through urinary excretion (D. R. Waldo, 1968).

Lignin concentration in dietary crude fiber influences the extent but not the rate of its digestion. Digestion of lignified fiber proceeds as if cellulose consists of a digestible and an indigestible component. Passage of indigestible lignin is proportional to the amount present. Potentially digestible lignin disappears both by digestion and passage (D. R. Waldo, L. W. Smith, and E. L. Cox, 1972).

Pasture bloat is a serious problem, sporadically causing morbidity and mortality in cattle and sheep grazing lush legume pastures. Alfalfa contains saponins which are toxic and may cause bloat. Bloat symptoms were produced experimentally by oral or intravenous administration of alfalfa saponins. The toxic level of saponins for sheep was 50 grams oral, 1 gram i.v. Respiration failure precedes cardiac failure. Test sheep were bloat susceptible as I. L. Lindahl and his colleagues demonstrated by preliminary tests with drenches of Ladino clover or alfalfa juice. Intraruminal, i.v., and intraintestinal administration of alfalfa saponins reduced ruminal mobility, suppressed eructation, and stabilized frothy bloat. Alfalfa saponins are toxic for sheep, but these researchers did not conclude that their experiments demonstrated that alfalfa saponins are the only cause of bloat on alfalfa pastures.

Thyroprotein (TP) fed to lactating cows after the first 50 days of lactation produces a 15 to 20 percent increase in lactation. This response can be sustained only if increased concentrate feed is provided to supply the necessary nutrients. Research at Beltsville compared identical twins fed 128 percent of the Morrison feeding standards—to one twin with TP; to the other without TP. The controls averaged 9,734 lb. of fat-corrected milk (FCM); the TP twins, 9,245 lb. One set of identical triplets produced as follows: 9,110 lb. FCM by the cow on the Morrison standard feed intake; 11,195 lb. FCM by the cow on the 125 percent Morrison standard intake; and 9,988 lb. FCM by one cow on 125 percent Morrison standard intake; and 9,988 lb. FCM by one cow on 125 percent Morrison standard plus TP. On a whole lactation basis, feeding extra grain without TP increased milk production as much as feeding extra grain with TP (L. A. Moore, 1958).

About 1950, Tom Jukes, then at American Cyanamid, discovered that subtherapeutic levels of antibiotics in pig and poultry feeds increased both rate of gain and feed efficiency in young animals. Jukes' findings were soon confirmed in many laboratories; subtherapeutic antibiotic feeding became general. From the very first, many veterinarians opposed feed use of antibiotics on the grounds that resistant strains of bacteria would emerge and compromise therapeutic use. Resistant strains did emerge, but this fact did not nullify the growth and feed efficiency benefits of antibiotic use nor has it compromised therapeutic use of antibiotics.

Feed use of antibiotics, coccidiostats, and high energy diets fed to genetically fast-growing stock have been major factors in reducing the cost per pound of producing broilers from 29.8 cents per pound to 14.2 cents, in current dollars, from 1948 to 1972 (Lyle P. Schertz and others, 1979, p. 173). Research at Beltsville demonstrated that subtherapeutic levels of aureomycin added to a corn-soybean diet containing vitamin B12 increased gain and feed efficiency of growing chickens (L. J. Machlin and others, 1952). Similar results with growing pigs were obtained at Beltsville. There was no effect of subtherapeutic aureomycin feed on swine reproduction (R. J. Davey and others, 1955).

Fat provides feed energy to animals in concentrated form—about twice as many calories or grams as starch. Kind and amount of fat—saturated or polyunsaturated in the feed, or no fat at all—affects the kind of fat deposited in nonruminant flesh or in eggs (cf "soft pork", p. 72). Research at Beltsville compared the effects on laying hens of a fat-free diet, the same diet plus 5 percent lard, and a conventional laying diet. Yolk fat in eggs from the three recipient groups of hens contained 3.68 percent, 7.70 percent, and 23.62 percent of polyunsaturated linoleic acid (18:2), respectively. Egg production and hatchability were lower in the fat-free diet and in the lard-supplemented diet than in the group receiving the conventional diet (E. C. Miller and others, 1963).

High and low energy diets fed to York and Duroc lines of swine selectively bred for high and low fat content of carcass affected the rate of gain and carcass composition. The low energy diet contributed two-thirds as much metabolizable energy (ME) as the high energy diets. Following is a summary of results:

Line	Energy Diet	Carcass Weight kg	Fat kg	Lean kg	Bone kg
York Highfat	High	66.7	34.4	23.7	6.3
Duroc Highfat	High	74.7	45.0	21.7	5.0
York Highfat	Low	55.9	22.7	24.8	6.1
Duroc Highfat	Low	57.9	31.4	19.3	4.9
York Lowfat	High	68.1	22.2	30.2	7.2
Duroc Lowfat	High	74.8	37.0	28.0	7.1
York Lowfat	Low	54.1	18.5	26.6	6.6
Duroc Lowfat	Low	58.1	27.4	25.6	6.6

There was an overall 20 percent reduction in rate of gain and a 4 percent improvement in feed efficiency when energy intake was reduced. The carcasses from genetically obese lines contained more fat than their genetically lean contemporaries of the same breed on both high and low energy diets. Both genetically obese and genetically lean pigs were leaner when fed the low energy diet than their contemporaries of the same breed fed the high energy diet (R. J. Davey, D. P. Morgan, and C. M. Kincaid, 1969).

Body composition in live animals is traditionally estimated visually, especially in pricing slaughter cattle. Objective measurements for use in determining energetic efficiency in nutrition studies, as well as a check on the accuracy of visual estimates, are important. One method of determining lean body mass is based on distribution of 50 ml injected (IV) nontoxic water-soluble antipyrine. Fixed amounts of antipyrine reach equilibration in all parts of lean body tissues in 25 hours post injection. Blood samples for antipyrine content reflect total dilution of injected antipyrine. Body water estimates range from 43.9 percent to 63.3 percent in animals varying in fatness. Body water is highly correlated with lean body mass. Estimates of 13.9 percent to 40.1 percent body fat agree closely with specific gravity and chemical analyses determinations of body fat and lean. The specific gravity of 30 cattle tested varied from 1.017 to 1.070, and was highly correlated with percent of separable fat in 9-10-11 rib carcass samples. Percent of body fat may be estimated by the equation:

Percent body fat = 100 (4.802/Sp.Gr. -4.366) (H. F. Kraybill et al., 1951 and 1952).

Physiology of Reproduction

Cattle—Calf crop varies very widely in various locations and management conditions. At the Front Royal, VA, and Iberia, LA, stations in 1956 and 1957, the percentages of calves weaned of cows bred were about 74 percent and 64 percent, respectively. Failures to conceive or early embryo mortality at Front Royal and at Iberia were 12 percent and 20 percent, respectively; fetal mortality, 2 percent and 4 percent; perinatal mortality, 11 percent at both stations; and later mortality before weaning, 1 percent at both stations (Wiltbank et al., 1961).

Calf crop is reduced by failure of fertilization, by embryonic and fetal mortality, and by perinatal mortality, often resulting from dystocia. Severe feed restriction suppresses reproduction. Among beef cows held at submaintenance protein or energy intake for long periods of time, e.g. winter or drought periods, reproduction may be delayed or may fail entirely. Groups of heifers fed high-, medium-, and low-protein rations in combination with high-, medium-, and low-energy diet content were studied at Beltsville and at Iberia. The Maryland heifers on low-energy rations did not reach puberty. Among those on low-energy - low-protein rations were several cases of urolagnia. Heifers on high energy rations became excessively fat. Frequencies of dystocia and perinatal calf mortality were high (Wiltbank et al., 1965, USDA *Technical Bulletin* 1314).

The anestrous post partum period is shorter for milked cows than for suckled cows; the interval was 104 days for suckled cows, 74 days for milked cows, as determined from data on milking Shorthorn cows at Beltsville from 1934 to 1955. The number of services per conception for suckled cows was 1.84; for milked cows, 1.54 (J. N. Wiltbank and A. C. Cook, 1958).

Uterine infection may be a contributing, but not a principal, cause of "repeat breeding" in the absence of *B. abortus*. Material flushed from the uteri of 69 "repeat breeder" cows 16 days post coitus showed only 8 to be infected, 1 of these with *B. abortus*. Three embryos were recovered from infected uteri, 31 from "normal" uteri. The authors

of the study concluded that bacterial infection is not a principal factor in repeat breeding. A high incidence of early embryonic mortality occurs in "repeat breeder" cows; among eight such cows there were five cases of mortality 35 days post conception (H. W. Hawk et al., 1963).

Artificial insemination and control of season of parturition would be greatly facilitated if estrus and associated ovulation were synchronized. Several hormones are involved in these processes, including estrogens, gonadotrophic hormones, lutenizing hormones, and progestogens. Their interaction and sequence determine the onset of estrus, ovulation, uterine receptivity to embryo implantation, maintenance of pregnancy, and, finally, parturition. In a study by Jim Wiltbank and his colleagues, injections of the estrogen estradiol valerate in cycling heifers on day 15 or 16 of the estrus cycle resulted in cystic ovaries. Injection on cycle day 8 resulted in corpus lutum regression and estrus in about half the treated heifers. Only one pregnancy resulted from mating at the induced estrus (J. N. Wiltbank, J. B. Ingalls, and W. W. Rowden, 1961).

Estrus was suppressed in heifers by feeding the progesterone medroxy progesterone acetate (MPA) for 9 days; estradiol valerate was injected on the tenth day. Two days later, FSH was injected intramuscularly in doses of 3.12, 6.25, 12.5, or 25 mg to groups of heifers. Ova shed by the respective groups averaged 1.1, 2.1, 8.6, and 14.6. Fertilization rates were 91.5, 93.8, 79.4, and 83.5 percent. There is high variability on the number of ovulations and subsequent conceptions. Twins may be desirable, but perinatal death loss in larger litters is excessive.

Poultry—Parthenogenesis—development of unfertilized eggs, resulting in many successive generations of females—is commonplace among some insect species, e.g. aphids. Spontaneous parthenogenesis in mammalian livestock species and laboratory mammals has not been demonatrated. No experimentally induced mammalian parthenote has lived to term. About 1952, M. W. Olsen at Beltsville discovered in turkeys the first spontaneous occurrence of parthenogenesis in homeothermic animals. All parthnogenetic turkeys are males. They are diploid. The second polar body fuses with the egg pronucleus to initiate embryonic development.

Olsen (1969, 1973) selectively bred a strain of Beltsville small white turkeys for high incidence of parthenogenesis. During the period 1952-71, 50 males lived to maturity, but only about 20 percent of them produced semen. One was backcrossed to his dam. Nine adult turkeys—four males and five females—resulted. This basic research by Dr. Olsen and his colleagues has received worldwide scientific recognition.

About 22 percent of incubated eggs from virgin and other nonmated Beltsville Small White turkeys initiated parthenogenetic development. Parthenogenesis occurs occasionally in chicken eggs, especially in eggs of the Dark Cornish variety.

Sheep—Rams with "poor" breeding records have 60 percent to 90 percent tailless sperm, while rams with "good" records have significantly fewer tailless sperm (O. Emik and G. Sidwell, 1949). Sperm leakage from the vagina of artificially inseminated ewes may prevent fertilization. Sixty-two percent of sperm placed in the vaginae of ewes vulvo-vagina ligated 48 hours previously to prevent vaginal leakage, were recovered. This is compared to less than 1 percent from nonligated ewes. Sperm recovered from ewes previously treated with MAP preliminary to synchronized estrus included a higher proportion of tailless sperm than did the sperm recovered from controls (H. W. Hawk and H. H. Conley, 1971).

Lifetime lamb production of ewes which exhibited estrus as lambs exceeded lamb production of ewes first exhibiting estrus as yearlings among the range Rambouillet, Targhee, and Columbia flocks at the Western Sheep Breeding Laboratory. About 12 percent of the ewes exhibited estrus during the first winter, but none were bred. Cumulative lifetime lamb production for the early puberty ewes exceeded lifetime lamb production of those with one later puberty by more than 15 kg per lamb per ewe (C. V. Hulet et al., 1969).

Mink—More than 10 years research on reproduction in the mink was reviewed by R. K. Enders in 1952. The account is complete from coitus, through ovulation, fertilization, implantation, parturition, and lactation to weaning.

Research on mink reproduction was initiated in 1938 under a grant to Dr. Enders from the special research fund established pursuant to the Bankhead-Jones Act. Administration and cooperation were transferred from the USDA to the Interior Department in 1940. In 1946, the project was returned to the USDA Animal Husbandry Division as a part of farmed fur animal research. Dr. Enders, professor at Swarthmore, became a cooperative agent and continued his

research, with the cooperation of C. F. Bassett and his colleagues at the U. S. Fur Animal Experiment Station at Saratoga, NY.

Mink in northern latitudes normally breed during the short days of February and March. Ovulation follows copulation. Implantation is delayed from 20 to 70 days, the longest delay when coitus and ovulation occur early, a shorter period when coitus occurs in the final days of the breeding season. The lengthening daylight period appears to be the signal for terminating the breeding season. Gestation after implantation lasts about 30 days.

From 10 to 30 percent of mink females fail to breed. Some of these have cystic, some atretic ovarian follicles. Some copulate, ovulate, but become pseudopregnant, usually after coitus that is very early or very late in the breeding season. A few resist coitus although ovarian and genital development appear to be normal. Restrained coitus in such females may result in pregnancy. Ovulation was not induced by injections of estrogen or pregnant mare serum.

The origin and growth of hair in fetal and post partum mink were described by Ethel Dolnick at Beltsville (1959). Earliest hair buds appear in the face of the 32-day postcoitus fetus, in other body regions in the 40-day fetus. In the 48-day fetus, fat cells surround the developing hair follicles and appear to be related to the development of the follicle. Tufts of hairs, each developed from a single follicle, emerge through a single epidermal orifice in the 120-day post partum mink.

Environment and Productivity

Analyses of environmental changes affecting the Beltsville Holstein herd were made over a 7 year period. Net energy consumption was the most important factor associated with changes in milk production. There may be genetic factors which affect feed consumption.

High ambient temperatures reduce growth rate in cattle, sheep, and hogs. Air movement, high shade, and evaporative cooling are among the devices used to make animals more comfortable and productive in hot weather. Weather also has important indirect effects on ruminant productivity. Drought reduces forage production and weaning weights of calves and lambs are below normal. Data for more than 7,000 calves weaned at Miles City, 1927-1953, showed that calf weaning weights were below average when summer rainfall was less than 4 inches (R. T. Clark et al., 1958; USDA *Technical Bulletin* 1181).

There is a wide genetic variation in heat tolerance among ruminant species and breeds. Several factors affecting relative heat tolerance in cattle are—1) capability of promoting heat loss from the body; 2) efficiency of energy utilization; and 3) tolerance for high rectal temperature and high respiratory rate. Sindhi-Holstein crossbreds have to lose only 57 percent as much heat per square meter of body surface as Holsteins in order to maintain hemathermy. Sweat glands are the principal mechanism for evaporative cooling in dairy cattle. The rate of surface evaporation is correlated with ambient air temperature, $r = +.76$, and with relative humidity, $r = .47$ (R. E. McDowell, M. D. Barrada, and D. H. K. Lee, 1961).

Jim Ota and Ed McNally (1961) reported from the South Central Poultry Laboratory (SCPL) that broiler condemnation rate during inspection at time of slaughter is highest in winter, especially in the Southern States. In 1959, condemnation rates were as follows: Maine, 1.26 percent; Delaware, 1.48 percent; Georgia, 1.74 percent; Alabama, 1.82 percent; and Mississippi, 2.19 percent. Ota and McNally attributed the higher southern rates to lack of insulation in comparison to Maine. They advocated more insulation to reduce heat loss in the winter and forced ventilation to increase heat tolerance in the summer.

Broiler chicks were grown to 8 weeks with diurnal room temperature cycle of 4.4°C to 15.6°C, with access to infrared heat lamps, compared with control chicks brooded at constant room temperatures of first week, 35°C; second week, 32.2°C; third week, 21.2°C; and fourth through eighth week, 15.6°C. Cyclic chicks had lower feed efficiency, higher mortality, and higher condemnation rates than the daily constant temperature chicks (J. G. Griffin et al., 1969).

Henry Siegel (1969) at the Southeast Poultry Laboratory in Georgia described the physiology of temperature regulation in the chicken. The core of the chicken's body is homeothermic. The exposed body surface temperatures vary with ambient temperature. Surges of blood to the feet in cold weather prevent freezing.

Chicks infected with *Mycoplasma gallisepticum* and noninfected chicks were brooded at the SCPL in 14 trials, to deter-

mine whether high and/or low and variable ambient temperature stress increased broiler mortality and condemnation. *M. gallisepticum* chicks exposed to -3.9°C to coma recovered without increased mortality or condemnation. Ambient temperature varying cyclically from 4°C-15°C during the first 4 weeks posthatch increased mortality but not condemnation of noninfected birds. Mortality and condemnation of infected chicks was high, 20 percent and 16 percent, but was not increased by short-term low temperature exposure. Holding chicks 2 hours at 51.7°C, 20 percent relative humidity, did not increase mortality or condemnation significantly (F. N. Reece, J. W. Deaton, and T. H. Vardamon, 1969).

In the fifties, the advent of jet aircraft breaking the sound barrier brought allegations of stampede losses in livestock and poultry herds and flocks. An experimental swine breeding herd was established at Beltsville to determine the validity of the alleged impact of jet noise on pigs.

Pigs were exposed to simulated jet noise, 100-130 decibles, at all phases of their life cycle. Initial exposure resulted in increased heart rate but no apparent injury to pigs exposed to 120 decibels 12 hours a day for 98 days. Estrus sows and boars were exposed during copulation; some sows walked away; others did not (J. Bond et al., 1956; USDA *Technical Bulletin* 1280).

Avian Leukosis

Avian leukosis was a major cause of mortality and morbidity among laying hens and broiler chickens in the United States from 1932 to 1972. The Regional Poultry Research Laboratory (RPRL) was established in 1937 to conduct, in cooperation with State experiment stations in the northeastern region, basic research in genetics and pathology which would control or eradicate the disease.

The possibility of immunization was established in 1946 when B. R. Burmester and colleagues demonstrated that a small dose of implanted tumor cells produces local tumors in chickens and an immunity which cannot be overwhelmed by a large or repeated dose of the same agent. Plasma from birds hyperimmunized against a lymphoid tumor when injected into chicks implanted with the same tumor strain reduced tumor-caused mortality.

In 1956 Burmester and R. F. Gentry inoculated susceptible line-15 chickens with graded doses of visceral lymphonatosis virus. The number of days from the day of inoculation to the day of death from lymphonatosis was proportional to the logarithm of dose. L. B. Crittenden and Burmester (1969) reported that genes tva^r and tvb^r control resistance to subgroup A (leukosissarcoma) and subgroup B (Marek's-erythroblastosis) by preventing virus penetration of the cell surface. The causative agent of Marek's disease was discovered to be a herpes virus. This discovery was made independently at RPRL and in England in 1967. Research at RPRL isolated and tested a turkey herpes virus that infected but did not kill chickens. Purchase and Okazaki at RPRL in 1970 used the turkey virus to develop a vaccine (cf. Burmester and Purchase, 1979). H. G. Purchase and W. Okazaki received a Tom Newman Memorial Award (Anon. 1973) in recognition of their contribution.

The vaccine came into general use about 1973. Its use resulted in the first field control of a neoplastic disease by immunization. This achievement was a major contribution to research in cancer, generally, in man and other animals.

Economically, immunization against Marek's reduces the annual cost of production of broilers and eggs in the United States by many millions of dollars.

PERIOD FOUR: 1973 TO DATE. . . .AND TOMORROW
REORIENTATION

In this post-Vietnam, post-Watergate period all roles of the Federal government, including research, have been subject to continual unmerited public criticism.

The ARS reorganization of 1972 shifted focus from animal species to science disciplines underlying major problems in livestock and poultry production and products. Management of research was decentralized, with regional directors responsible for research operations in the Northeast, North Central, Southern, and Western Regions. Central direction, planning, budgeting, and coordination are accomplished by the ARS Administrator in Washington, DC; the National Planning Staff and the Deputy Director ARS to whom they report are located at Beltsville. The Deputy Director is responsible for review evaluation and for the establishment of priorities.

Major achievements during this period include frozen storage of semen of swine and poultry species and of embryos of several mammalian species and their subsequent implantation and development.

Basic research in energy metabolism, especially of dairy cattle, has provided information essential to feed-efficient milk and meat production. Integrated systems of selective breeding, nutrition, controlled reproduction, environmental and waste management, product modification to meet consumer preference, and marketing were developed through simulation and field studies and applied on a large scale. Large-scale cattle feedlot, dairy, swine, broiler, turkey and egg enterprises became linked to feed supply, processing, and marketing entities.

Diethylstilbestrol (DES) was prohibited, its role in part replaced by estradiol—possibly less hazardous, certainly more difficult to regulate. Public concern with animal rights led to statutory regulation of research use of laboratory animals, and a widespread public interest in vegetarian or ovo-lacto-vegetarian diets.

These trends wax and wane as information and propaganda on the relation of diet and health are presented, challenged, and modified, e.g. on the role of cholesterol, and the probable relation of both saturated and polyunsaturated fats to cancer. Per capita consumption of fluid whole milk, beef, and eggs declined because of publicity-generated public concern. Poultry consumption, broilers and turkeys, continue to increase as economical sources of lean meat, while the fat content of broilers increased, as their individual broiler market weight doubled and the still fatter roaster came into the supermarket.

Organization and Administration

In 1972, research in USDA was reoriented according to disciplinary lines and interdisciplinary groups, with increased emphasis on mission-oriented basic research. Areas of emphasis included reproductive physiology, e.g. freezing preservation of semen and embryos; and integrated breeding, nutritional, environmental, disease control, and automated management systems.

Talcott Edminster was ARS Administrator; Paul D. Delay Assistant Administrator for Livestock and Veterinary Research located in Washington, DC. The National Program Staff, located at Beltsville, included E. J. Warwick for beef cattle; R. B. Hodgson for dairy cattle; J. A. Newmann for poultry; C. E. Terrill for sheep and other animals; and R. J. Geritts for swine. ARS research was managed through four regional deputy administrators and their staffs, located at Beltsville, MD, Peoria, IL, New Orleans, LA, and Albany, CA.

Animal and Poultry Husbandry Research at Beltsville was consolidated into an Animal Physiology and Genetics Institute, James W. Smith, Chairman. After a long and courageous battle with cancer, Edminster died, and he was succeeded as ARS Administrator by Terry Kinney.

Further reorganization occurred; this was a period of severe constraints on funds and personnel. Priority was given to basic research, administered in part by competitive grant. Applied research that was deemed to be of lower priority and locations of lower productivity or potential were eliminated. Some retirees were not replaced.

In 1982 Thomas J. Army was Deputy Administrator with primary responsibility under the Administrator for research programs and priorities. The National Program Staff animal science members were Charles A. Kiddy for dairy, Dayarl King for poultry, Daniel B. Laster for physiology, and Roger J. Geritts for swine. In the Northeastern Region, located at Beltsville, Glen Vandenberg was acting Regional Administrator. Animal science research was organized and administered as follows: an Animal Science Institute, Lewis W. Smith, Chairman, had replaced the Physiology and Genetics Institute. Within this Institute were the Animal Improvement Programs Laboratory, Frank N. Dickinson, chief; the Avian Physiology Laboratory, Thomas Sexton, chief; the Milk Secretion and Mastitis Laboratory, Robert H. Miller, chief; the Nonruminant Animal Nutrition Laboratory, Ben Bereskin, technical advisor; the Reproduction Laboratory, Harold Hawk, chief; the Ruminant Nutrition Laboratory, Paul Moe, chief; and the Meat Science Research Laboratory, Anthony Kotula, chief.

Animal science research at other locations in the Northeastern Region was located as follows: US Regional Pasture Research Laboratory at University Park, PA, under Stephen M. Abrams; nutritional evaluation of forage crops quality, at the Soil Plant Nutrition Laboratory, Ithaca, NY, William House, animal physiology; and at Cornell University, James Fitzgerald, sheep research; in Georgetown, DE, poultry research laboratory, James D. May, leader; in Philadelphia, PA, the Eastern Regional Research Center, dairy research under H. Farrell, Jr., leader; meat and meat products research

under Robert Benedict, leader; In the North Carolina Region, Paul J. Fitzgerald, Regional Administrator was located at Peoria, IL, and animal science research was conducted at West Lafayette, IN, by Dewey L. Harris, Animal Genetics Research Leader, and by Vernon A. Garwood, Poultry Genetics Research leader (poultry genetics has been terminated at the location and Garwood and Phillip Lowe were transferred to Georgetown, DE); at Clay Center, NE, the Roman L. Hruska Meat Animals Research Center, Robert L. Oltjen, Director. Research is conducted with beef cattle, sheep and swine and their food products organized as follows: Nutrition Research, Wilson G. Pond, leader; Reproduction Research, John J. Ford, leader; Production Systems Research, Ling-Jung Koong, leader; Genetics and Breeding Research, Larry V. Cundiff, leader; Meats Research, Russell H. Cross, leader.

In Madison, WI, research is being conducted at the US Dairy Forage Research Center, Raymond J. Bula, Administrator; in East Lansing, MI, in the Regional Poultry Laboratory, Avian Leukosis Research by Richard L. Witter, leader; in Fargo, ND, in the Metabolism and Radiation Research Laboratory, Animal Metabolism under Peter Aschbacker, leader; in Mandan, ND, the Northern Great Plains Research Laboratory, Forage and Range Animal Nutrition, by James F. Karn.

In the Western Region H. C. Cox, Regional Administrator, is based in Albany, CA. At the Jornada Experimental Range, New Mexico, Dean M. Anderson heads Animal Nutrition; in Logan, UT, Dairy Management Research is under Robert C. Lamb, leader; in Miles City, MT, the Livestock and Range Research Station is directed by Robert A. Bellows, leader; in Dubois, ID, the US Sheep Experiment Station is headed by Clarence V. Hulet, leader.

Edgar L. Kendrick is Regional Administrator of the Southern Region, headquartered in New Orleans, LA. Under him Floyd P. Horn, in El Reno, OK, conducts beef cattle research; at Mississippi State James W. Deaton is director of the South Central Poultry Research Laboratory, and Floyd N. Reece, leader, was in charge of poultry mechanization; in Brooksville, FL, beef cattle research was under William C. Burns, leader; in Athens, GA, at the Richard B. Russell Agriculture Research Center, meat quality research (including poultry meat) is under Leroy C. Blankenship, leader, and animal physiology research is under Robert R. Kraeling, leader; at the Southeast Poultry Laboratory, Charles W. Beard, director, poultry physiology research is under Hubert S. Siegel, leader, and poultry genetics research is under Henry L. Marks, leader; at Watkinsville, GA, forage/livestock management systems research is being done by John A. Striedeman, animal physiologist; and in Knoxville, TN, beef cattle genetics research is led by Will T. Butts.

In September 1983, ARS announced consolidation of research management and administration, with reduction in the number of positions, the institution of a 10-member Administrators' Council, and the establishment of new, and expanding, current-research programs with resources accrued from these changes.

Highlights

Diethylstilbestrol, which when ingested by rats may result in cancer, was widely used during the fifties and sixties to improve rate of gain and feed efficiency of cattle. Its continued use, always on a "no residue" basis, was challenged in the seventies. Research by Aschbacher at Fargo demonstrated a detectable amount of DES, about 0.1 ppb, in edible tissues of cattle 7 days after administration. This finding was critical to the subsequent withdrawal of the approved uses of DES for feedlot cattle by FDA, pursuant to the requirements of the Delaney Clause of the Food, Drug and Cosmetics Act.

Recent and current research on preservation of semen and embryos for artificial insemination and transfer is innovative and productive. Preservation of boar semen is a recent achievement to which Vernon Pursel at Beltsville has made an important contribution.

A major limiting factor in efficient sheep production is the small number of lambs weaned per ewe bred. Use of the prolific Finnsheep in the production of crossbred brood-ewes promises to lead to substantial improvements in lambs weaned per ewe bred, as shown by several years research at Clay Center, NE.

The proportion of forage in milk cow diets has decreased as milk production per cow has increased. Research evaluated by D. R. Waldo and N. S. Jorgenson shows that crude fiber, principally supplied by forage, is necessary to assure acceptable percentage of butterfat in the milk produced.

The life cycle energy cost of producing edible protein is about three times as high for beef as for broilers. Long term potential increases in genetic capacity for offspring per female, growth rate, and decrease in percentage of fat in carcass can greatly reduce the life cycle energy cost (Gordon Dickerson, Meat Animal Research Center, Clay Center, NE).

Cattle adapt genetically to environment. Twelve years of comparison of Herefords bred at Miles City, MT, and at Brooksville, FL, reciprocally exchanged and indigenous stocks demonstrated that heifers of each stock were significantly heavier in the location where they were bred than were the heifers of similar breeding in the alternate location.

About 50 million tons of collectible fecal and urinary dry matter is voided annually by livestock and poultry. Large enterprises, especially those near dwellings, have problems managing the wastes without unacceptable odor and fly problems. Methane manufacture, incineration, feed use, and the traditional use as fertilizer provide potential disposal methods. Increasing amounts are used as ruminant feed, at best only a partial outlet. Fertilizer use is often the most cost-effective outlet when cropland is available in sufficient acreage to provide productive fertilizer use within 10 miles of the livestock or poultry enterprise.

Genetics and Breeding

Among meat animal and poultry species, life-cycle feed, fixed and variable costs of facilities, care, and management vary widely. Integrated breeding, feeding, and marketing management systems have common variables including maternal and progeny feed efficiencies, number of progeny per breeding female, generation interval, and environmental control and waste management.

Calculated comparative efficiencies of meat animal species for production of edible meat protein are shown in the following table (G. E. Dickerson, 1978).

Life Cycle Energy Cost of Producing One kg of Edible Protein

	(MCal ME)[1]			
	Dam	Individual	Total	Dollars
Broiler	4.8	66.7	71.5	5
Turkey	4.8	71.6	76.4	6
Rabbit	17.7	77.6	94.3	7
Pork	47.8	95.6	143.4	11
Lamb	281.9	143.4	425.3	15
Beef	353.5	82.1	435.6	16

[1] calculated from data in Dickerson's Table 1.

Long Term Potential Increase in Genetic Capacity (Percent)

	Now	Potential	Now	Potential	Now	Potential
Broiler	100	150	30.3	36.6	13	8
Turkey	60	90	19.2	27.1	13	8
Rabbit	40	80	122.3	36.0	6.8	4.0
Pork	12	24	28.4	36.0	32	15
Lamb	1.4	4.0	18.2	36.0	36	15
Beef	0.8	1.8	14.8	21.3	32	15

The dollar estimates include relative costs of forage, concentrates, housing care, and other fixed and variable costs associated with production of meat animals.

Long-term potential increases in genetic capacity will, when achieved, reduce costs of animal protein production, resulting in hundreds of millions of dollars savings to consumers. The average percentage increase in the three major variables—offspring per female, relative growth rate, and percentage of fat in carcass—would be as follows: broilers 35 percent, turkeys 45 percent, rabbits 65 percent, pork 60 percent, lamb 120 percent, and beef 80 percent.

Beef Cattle—Net economic efficiency of beef production is limited by cow herd costs resulting from increase of cow size, dystocia, and infertility.

Data from Lincoln and Fort Robinson, NE, breeding herds showed that calf mortality increased 0.78 percent per kg increase in calf birth weight, and dystocia increased 2.4 percent. An 80-percent calf crop reared with estimated cow costs—feed and nonfeed—at $125 per head resulted in weaning calf cost of $156.25. Dickerson stated that selection among bulls used as sires for higher average daily gain (ADG) will increase calf birthweight before it increases cow size, but it is biologically feasible to select for both higher ADG and lower birthweight, thus limiting or reducing dystocia hazard (G. E. Dickerson, 1974).

Research, cooperative among the Animal Husbandry Division and Montana State University and University of Florida compared genetic stocks of Hereford cattle selectively bred at Miles City, MT, and Brooksville, FL, in productivity at each location.

Twelve years of research on genetic and environment interaction on line by location interactions were highly significant for weaning weights, weaning to spring ADG, yearling weight, and height at withers. Miles City yearling heifer weights were significantly higher in Montana than in Florida, and Montana line M. heifers were heavier than Florida line F^6 heifers in Montana. In Florida however, Florida line F^6 heifers were heavier than Montana M^1 heifers produced in Florida, indicating genetic adaptation to location where the respective lines were developed (M. Koger et al., 1979).

Poultry—In poultry breeding research, genetic change for egg production and egg quality traits was calculated from records of pedigreed strain-cross (TX1) progeny performance of about 24,000 pullets from 400 sires and 2,400 dams at 20 to 40 field locations. Yearly genetic gains in the economic index per bird from 1956 to 1959 was $16, while corresponding environmental trend average was a decline of $13 (T. S. Kashyap and others, 1981).

Retrospective index weightings, selection intensities, and genetic variables were used to predict genetic responses over a 5-year period. Predicted yearly change in economic value was $0.21. Mortality and egg production responded more favorably than predicted.

Dairy Herd Improvement (DHIA)—Holstein sires used for artificial insemination (AI) in DHIA had higher merit than those used in natural matings. Gross income per first lactation for daughters of AI sires of all breeds was $45 greater than for non-AI daughters. Average predicted differences for first lactation grade cows in DHIA in 1978 were as follows: Ayrshires 190kg milk; Brown Swiss 276kg; Guernsey 205kg; Holstein 263kg; Jersey 292kg; and Milking Shorthorn 226kg (R. L. Powell et al., 1980).

Lactation records for more than 35,000 dairy goats were kept for the period 1968-1978; these data have potential for sire evaluation. The average of 20,131 lactations of 275 days or more was 878 kg milk and 33 kg BF.

From 1959 to 1974, the number of US farms with milk cows decreased from 1.8 million to 0.4 million; the number of milk cows, from 16.8 million to 10.7 million. The average number of milk cows per farm carrying cows increased from 9 to 25. The number of large dairy farms has continued to increase. Now many farms have hundreds of cows. But in Wisconsin and New York, costs per hundred weight of milk produced were higher on farms with more than

100 cows than on farms with fewer than 100 cows.

Sheep—The relatively higher cost of producing edible protein from lamb as compared to broilers—a threefold difference—is largely due to difference in progeny per maternal parent—1.4 per ewe versus 100 per broiler breeder hen. Recent research using the prolific Finnsheep and other prolific exotic breeds in crosses with traditional US breeds promises to increase lamb protein production efficiency.

At the Meat Animal Research Center (MARC) at Clay Center, NE, the 4-year lamb production of crossbred ewes mated to Finnsheep was 105 lambs weaned per 100 ewes compared with 67 lambs per 100 purebred ewes, and 80 lambs per 100 Rambouillet ewes mated to muttonbreed sires. Dickerson (1977) concluded that use of crossbred ewes from matings of Finnsheep to Whiteface (e.g., Rambouillet), mated to muttonbreed rams (e.g., Suffolk or Hampshire) could reduce the cost of producing market lambs in the North Central States by 20 to 25 percent, as compared to a system using whiteface ewes mated to the same muttonbreed rams (North Central Regional Publ. 246, Univ. of Nebraska, 1973).

At the Dubois, ID, Sheep Experiment Station, the average annual lamb production by 1-, 2-, and 3-year old ewes was 58 for purebred Columbia, Rambouillet and Targhee ewes and 109 for half-Finnsheep crossbred ewes (1979 Progress Report by Price and Ercanbrack). Ninety percent of Finnsheep crossbreds lambed as 1-year olds while only 23 percent of purebreds did so.

Production of sheep and lamb meat per ewe increased from 13.6 kg per ewe in 1950 to 18.6 kg in 1972. In a Targhee line selected for early puberty for 8 years, 50 percent of 12-month old ewes lambed, compared with 20 percent for unselected control Targhees. Mature ewes of the new polypay breed at Dubois weaned 1.68 lambs per ewe exposed and 12-month old polypay ewes weaned 8.90 lambs per ewe exposed.

Swine—In swine breeding work at Beltsville a selection productivity index (SPI) was developed based on analyses of sow-litter records of 483 York and Duroc pigs, as follows: $SPI = 2.67N_a + 1.87N_{21} + 0.97W_{21}$ in which N_a is a number of pigs born alive per litter; 21^N is number alive at 21 days; and W_{21} is litter weight at 21 days. SPI heritability was 0.21 + 0.09. Average number of pigs per litter at 21 days: Yorks exceeded Durocs by one pig (B. Bereskin and L. T. Frobish, 1981).

M. W. Tess and his colleagues published a bioeconomic model for the analyses and projection of biological and economic factors which, singly and through interactions, determine the biological and economic life cycle cost of pork production in large scale, modified environment (Tess et al., 1983).

The base biological parameters for first and second parities were mating liveweight, gestation feed intake, maternal gestation in weight, percent of starting gilts farrowing, number of pigs born alive and number weaned per litter, and daily sow milk production in KcalME. Economic parameters include sow feed and pig feed per 100kg live hog produced, fixed and variable nonfeed costs, and interest. The total feed cost per 100kg live hog produced in 1983 was estimated as $48.59, the nonfeed costs, $37.97, total $87.89 or about $40 per 100 lb. liveweight produced.

The researchers simulation showed that the number of pigs weaned per litter had greater importance for economic than for biological efficiency. Doubling feed prices decreased the relative importance of number of pigs weaned per litter and magnified the effect of percent of fat at market weight.

Purebred, two- and three-breed specific crosses and rotational crossbreeding systems were compared. Cost reductions from crossbreeding were greater when pigs were marketed at 185 days post partum than when marketed at a uniform fixed weight. Reductions in nonfeed costs were greater than for feed costs. The best three-specific breed crossbreeding systems, using complementary, maternal, and paternal lines, permitted greater cost reductions than rotational crossing.

Breeding improvement based on an index of heritable traits indicated that changes in fatness dominated the index when the economic objective was reduction in cost of producing lean meat. When genetic progress for leanness is achieved, the trait will cease to dominate the index because heritability of the trait will decrease and cost per unit of genetic gain leanness will increase. When the objective was reduction in cost per kg liveweight, no single trait dominated the index.

The fatty acid composition of adipose tissue was analyzed from genetically obese and lean pigs and from contem-

porary crossbreds. All lines showed an increasing proportion of saturated fatty acids and obesity with increasing age. Adipose tissue at six months of age contained the following percentages of 16:0 saturated and 18:2 polyunsaturated fatty acids: the obese line 24.57 + 0.51 and 13.97 + 0.52; the lean line 22.55 + 0.53 and 19.7 + 0.53; and crossbred contemporaries 21.43 + 0.53 and 22.30 + 0.53 (R. A. Scott, S. G. Cornelius, and H. J. Mersmann, 1981).

Nutrition

Cattle—Diethylstilbestrol (DES) was widely used in feedlot steers to increase rate of gain and feed efficiency. Ear-implanted pellets usually increased average daily gain and feed efficiency by about 10 percent. DES use was permitted on a no-residue basis under the Delaney clause of the Food, Drug, and Cosmetics Act. Allegations of residues in edible tissues of treated steers led to rigorous experimental tests at ARS laboratories at Beltsville and Fargo, ND.

At Beltsville two 20-milligram DES pellets were implanted in the ears of steers which were slaughtered 14, 28, 56, 84, or 119 days post implant. Implant absorption followed an exponential curve: $y = 11.6\ e^{0.014x}$ in which y = mgDES; e is the base of natural logarithms; and x is days post implant. DES analyses by gas-liquid chromatography, sensitive to .5 ppb, of muscle, kidney and liver samples detected no DES 56 days or longer post implant (T. S. Rumsey et al., 1974).

At Fargo, radioactive DES was administered to steers that were sacrificed 24, 48, 72, 120, 168 or 240 hours later. DES was detected (0.1 ppb) in liver samples of one steer slaughtered 168 hours after administration. According to the investigators, "Under the present interpretation of the food additive amendment of PL85-259 of the Federal Food, Drug, and Cosmetics Act, these minute quantities have legal significance" (P. W. Aschbacher and E. J. Thacker, 1974).

Subsequently, following several months of public hearings, FDA withdrew approval of DES use in feedlot cattle.

In an investigation into winter maintenance energy requirements for beef cows, conducted at the Meat Animal Research Center, Clay Center, NE, four diverse groups of crossbred, nonlactating, nonpregnant cows were wintered at three levels of energy intake. The initial weights were Angus x Hereford (AH), 527 kg; Charolais x Hereford (CH), 561 kg; Jersey x Hereford (JH), 450 kg; and Swiss x Hereford (SH), 566 kg. Feed intakes for all four groups were 90 $kcal/kg^{3/4}$, 150$kcal/kg^{3/4}$, and ad lib. All groups lost 10 to 15 percent of initial weight in 140 days at the 90 kcal plane. Changes at the 150 kcal plane were AH, +9 percent; CH, -5 percent; JH, +2 percent, and SH, +4 percent. Gains for the ad lib. group were AH, 24 percent; CH, 12 percent; JH, 19 percent; and SH, 21 percent (T. G. Jenkins and C. L. Ferrell, 1983).

Energy intake and efficiency of energy metabolism are major factors determining feed cost of milk production. For each increment of feed intake equal to maintenance requirement, average digestibility decreases about four percent. Energetic efficiency of milk production varies with the metabolizable energy (ME) content of the diet:

MCal ME kg/DM	2.0 energetic efficiency of milk production 60 percent
	2.6 energetic efficiency of milk production 63 percent
	3.0 energetic efficiency of milk production 64 percent

assuming 100 kcalME kg¾ body weight for maintenance (H. F. Tyrrell and P. W. Moe, 1975).

There is little evidence that energetic efficiency of milk production varies with milk yield, stage of lactation, or breed of animal. Energy balance studies—indirect calorimetry, with lactating and non-lactating cows—demonstrated that energy values of corn with hard endosperm are not different from the energy values of corn with soft endosperm. Energy values for cracked corn fed at maintenance level to nonlacting cows was 3.38 MCal/ME/kg while at 2.5 times maintenance level to lactating cows the value was 2.67 MCal/ME/kg (Moe and Tyrrell, 1979).

Maintenance requirements of lactating cows, estimated by pooled linear regression within 32 diets, 350 energy balance trials, at Beltsville by Paul Moe (1981), gave estimates of 122.1 or 111.3 kcal ME/kg¾ depending on whether ME intake or milk energy output was the dependent variable, or net energy for lactation (NE) 78.9 and 68.7 kcal NE/kg¾ respectively. The mean of these NE estimates, 75.3, is almost identical with the 73.5 NE/kcal/kg¾ value for fasting heat production found at Beltsville for nonlactating, nonpregnant cows.

Moe stated that his then-current estimate of efficiency of ME use for milk production was 60 to 64 percent; this is lower then the earlier estimates of 68 to 70 percent (Moe, 1981).

As milk production per cow is increased, the proportion of roughage in the ration must decrease. The rumen capacity of the cow is limiting. D. R. Waldo and N. S. Jurgenson (1981) summarized current information on function of forages in dairy nutrition, factors affecting forage intake and digestibility, and amount of forage and other feed consumed by dairy. They credit the following table to G. E. Allen of the Economic Research Service (quantities of feeds are expressed in corn-equivalent feed units (CFU)).

Year	No. of Cows	Milk-kg millions	Dairy Feeds Consumed (Millions of kg/CFU)				
			Concentrate	Hay	Harv. For.	Pasture	Total
1958	23,896,000	55,169	15,954	13,883	9,584	17,946	57,362
1973	10,853,000	55,232	24,586	10,623	10,908	10,908	57,416

Proportion of concentrate in milk cow diets increased from 28 percent in 1958 to 43 percent in 1973; dry matter (DM) intake per cow increased from 3918kg in 1958 to 7627kg in 1973.

Functionally, forage fiber is correlated with chewing time and the percent of butterfat (BF) in milk produced. Cows ruminate less than 10 hours per day. About 17 percent of crude fiber is necessary in the ration to assure 3.5 percent BF in the milk. The average *ad lib.* intake of fresh forage digestible organic matter is about 1.4 times the intake in harvested forage.

Fat and vitamin A are key ingredients which must be added to nonfat milk solids to make adequate diets for calves weaned at birth and reared on whole-milk surrogates. Average dairy gain (ADG) for Holstein male calves reared to 112 days post partum on diets of skim milk plus additives is shown:

(a) 3.5 percent BF added, 445 grams/head/day (g/h/d)

(b) 3.5 percent tallow added, 411 g/h/d

(c) 3.5 percent tallow plus 0.2 percent cholesterol added, 487 g/h/d

(d) 7 percent tallow added, 596 g/h/d

(e) 7 percent tallow plus 0.2 percent cholesterol added, 583 g/h/d

The 7 percent tallow plus cholesterol diet increased blood lipid and cholesterol levels two- to threefold (T. R. Wrenn et al., 1980).

When whole milk and whole milk with 25 percent, 50 percent, or 75 percent of its protein heat-denatured were compared as diets for Holstein male calves, denatured protein had not changed body weight, nitrogen balance, nitrogen retention, or nitrogen digestion (G. P. Lynch and F. E. McDonough, 1980).

Poultry—Because widespread occurrence of DDT in aquatic organisms has been alleged to be a major cause of reproductive failure due to egg-shell thinning, e.g. in pelicans and peregrine falcons, its effect on domestic poultry was investigated. Research at Beltsville with chickens demonstrated only minor effects of DDT intake on shell thickness in chickens.

Diets containing DDT at 0, 10 or 50ppm with 1.5 percent or 3.5 percent calcium were fed to laying pullets and hens. According to the investigators, "DDT supplementation did not produce significant changes in egg production and livability or feed consumption, fertility and hatchability irrespective of calcium." (R. J. Lillie et al., 1973, p. 640). Egg shells from 2 year old hens were thinner, while those from pullets were thicker on DDT-supplemented diets than were shells

of control eggs. DDT residues in whole egg contents were as follows: control 0; lOppm DDT supplement 8ppm; 5Oppm DDT supplement, 43ppm.

Excessive fat, especially abdominal fat in poultry has increased as market weight of broilers and energy content of broiler diets has increased. Two groups of female broiler chickens, in an 8 week diet study, were fed at two levels of energy diet 0-4 weeks post hatch, then the same high energy diet (3,372 kcal ME/kg) 4-8 weeks. The females fed high energy diet from 0-8 weeks weighed 1,468g, ether extract 12.47 percent; those fed lower energy diet 0-4 weeks had an 8-week weight of 1,472g, ether extract 13.3 percent (J. W. Deaton et al., 1973).

Swine—In swine nutrition tests, barrows, initial weight 27kg, were fed at three levels of feed intake for 35 days, then reversed planes for a second 35-day period. The average daily gain for the three lots for the two periods were group one: +.54kg, -.25kg; group two: +.20kg, +.54kg; and group three: -.15kg +.54kg. Group three pigs, fed high plane during the second period, had higher viscera weight and higher fasting metabolism than group one, though slaughter weights were the same (L. J. Koong et al., 1982).

Growth rate of young pigs may be reduced by crowding. Average daily gain and feed efficiency of nursery-reared pigs from 5 to 10 weeks of age, penned in groups of 8, 12, or 16, with 0.25, 0.17 or 0.13 square meters floor space per pig, were measured. Groups reared on slotted floors were compared with groups reared on expanded metal floors. It was determined that the floor material had no effect on ADG or on feed efficiency. Increasing the number of pigs per pen did decrease ADG, but not feed efficiency (R. N. Lindvall, 1981).

Meat Quality—Meat quality, composition, and safety vary according to age, sex, species, and nutritional and environmental history of the slaughtered animals, and the conditions of processing, product storage, and subsequent treatment prior to consumption.

There is current interest, but slow adoption in practice, in using young bulls for beef. Young bulls generally gain faster in feedlot and yield leaner carcasses than steers or heifers. Quality of bull beef (marbling and tenderness) is generally slightly inferior to steer or heifer beef from contemporaries.

Average daily gain (ADG) and meat quality of five groups of yearling bulls were compared at MARC. Treatments of the five groups were as follows: 1) intact, 2) emasculator castration, 3) surgical castration, 4) intact with 30g zeranol implants, and 5) intact with 72mg zeranol implants. ADG for the five groups were 0.9kg, 0.9kg, 1.2kg, 1.4kg, and 1.5kg. Cross section area of *longissimus dorsi* was greatest in intact bulls, smallest in the emasculator group. Castrates required 4 percent more ME/kg gain; their meat had more marbling, lower shear values, and better flavor than that from intact bulls (K. E. Gregory and J. J. Ford, 1983).

Physiology of Reproduction

Cattle—The U. S. calf crop in 1979 was about 80 percent of cows bred; an increase to 85 percent would save $588 million in cow feed (E. J. Warwick In Beltsville Symposium III, 1979, pp. 413-421).

Cows bred at the Miles City Station from 1964-1977 numbered 12,827; of these 2,232 (17.4 percent) were open at the end of the 45-60 day breeding season. Perinatal calf death, mostly dystocia, was 821 (6.4 percent); calf death from birth to weaning was 372 (2.9 percent); calves weaned were 9,107 (71 percent). One hundred twenty-one cows were delivered by Caesarian section; subsequent pregnancy rate was 52.9 percent vs 79.9 percent for the herd average; for 49 cows with retained placenta, 82.2 percent; among 158 cases of prolapse, for primiparous cows 28 percent, for multiparous cows 58 percent (R. A. Bellows et al., 1979).

Freezing preservation of embryos facilitates increased propagation of genetically superior females and international traffic in specific pathogen-free, genetically superior stock. Use of a cryoprotectant, (e.g., DMSo or glycerol), slow cooling (1-2°C/minute) and storage at minus 196°C, have maintained viability in cattle, goat, and sheep embryos for several years. No success was reported in 1978 with preserving swine embryos by freezing. Embryos in the late morula and early blastula stages tolerate freezing more successfully than younger or older embryos (R. R. Maurer, 1978).

Repeat breeding of dairy cows results in longer intervals between calvings and loss in milk production. The average dairy cow lives 5 years and completes two lactations. Reduction in calving interval and reducing calf losses from the

current 10 percent to 4 percent could save $200 million a year (T. H. Blosser in Beltsville Symposium III, 1979, pp. 418-421).

Most "infertile" AI services, i.e., repeat breeding, is due to 1) insemination of cows not in estrus, 9 percent; 2) failure of fertilization of ripe ova, 13 percent; 3) death of developing embryos, 15 percent. Early embryo death is much higher when insemination is late and ovas are senescent, and when ambient temperature and humidity are high at time of insemination (H. W. Hawk in Beltsville Symposium III, pp. 19-29).

Several estimates indicate that as many as 50 percent of cows in estrus are missed, and as many as 20 percent reported ready for insemination are not yet in estrus. Vasectimized bulls may be used to detect cows in estrus. Seeking a method to improve accuracy of identification of estrus cows, four German shepherd dogs and two Labrador retrievers were trained to detect and respond to vaginal swab odors from estrous cows. Five trials were conducted with increasing accuracy, about 80 percent in the fifth trial. A sixth trial was conducted with urine samples. A seventh trial with live cows was 87.8 percent accurate (C. A. Kiddy, et al., 1978).

Among all animal diseases, mastitis may be the disease causing greatest economic loss. Annual losses from mastitis in milk cows was estimated by T. H. Blosser (1977) to be $1,297,000,000. This estimate includes loss in milk production, cost of drugs and veterinary services, and cow replacement costs. In 1965, mastitis research in the USDA and State agriculture experiment stations cost 17.7 scientist man years (SMYs) and $14,662,000; in 1976 the costs were 16 SMYs and $11,050,000.

Mastitis often follows careless use of, or defective, milking machines. Mastitis-related factors in current milking machines might be corrected by designs using alternates to two-phase milking with two-chambered milk cups (P. D. Thompson, 1979).

Growth inhibition was compared in trypticase-soybroth-tube cultures of branched and straight chain amines against five microorganisms (*Streptococccus agalactiae, S. uberus, Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae*) which are responsbile for 95 percent of mastitis infections. Branched alkyl chain amines were equally active as straight chain amines against gram positive bacteria, but not against gram negative bacteria. Inhibition of gram positive bacteria increased with chain length (M. D. Cullen et al., 1979).

Neutrophile polymorphs (white blood cells) are an essential body defense against mastitis. M. H. Paape et al. (1979) found about 50 million neutrophiles per multiliter of milk in cases of clinical mastitis. Despite this flux, neutrophile effectiveness in the mammary gland is reduced. Paape speculated that adrenocorticotrophic hormone may reduce the phagocytic capacity of neutrophiles.

Poultry—In layers, broilers, and turkeys, improved reproduction efficiency could yield savings of about $80 million, according to estimates by H. Graham Purchase. He suggested control of sex as a way of improving reproduction efficiency; economically it would be very advantageous, especially in chicken layer production, since most males are killed as day-old chicks (Beltsville Symposium III, 1979 pp. 413-421).

Artificial Insemination (AI) is currently used by primary chicken and turkey breeders. Capability to preserve semen up to 24 hours at temperatures above 0°C is needed to extend the use of genetically superior sires. Frozen semen would facilitate worldwide distribution (T. J. Sexton in Beltsville Symposium III, 1979, pp. 159-170).

Poultry semen extender contains an energy source, e.g. glucose, a dielating agent, e.g. milk, osmotic balance, mg chloride and Ma acetate, and an antibiotic, e.g. gentamycin. Sexton reported that semen stored at minus 196°C for 7 days gave 59 percent fertility in chickens. It was thawed in the presence of 4 percent DMSO.

Egg shell quality causes reduction in hatchability of broiler-breeder and turkey eggs. H. Opel stated that there was urgent need for a method of preserving turkey semen for use 6 to 8 hours after ejaculation (Beltsville Symposium III, 1979, pp. 51-59).

Sheep—In sheep principal causes of low fecundity are 1) restricted breeding season; 2) low fertility in the early postpartum period; 3) late puberty; and 4) perinatal mortality (C. V. Hulet in Beltsville Symposium III, 1979, pp. 31-40). Crossbreeding, selective breeding, and good management improve fecundity. No progress has been made in reducing embryonic mortality, which is often high early in the breeding season in hot climates.

Ram fertility varies with daylight period. Two groups of ram lambs were exposed to 1) an increasing daily light period from 8 hours on February 12, to 16 hours 8 weeks later; 2) decreasing light from 16 hours on February 12, to 8 hours 8 weeks later. Scrotal circumference in rams of group one decreased 10 percent; in group two rams it increased by 15 percent. At the end of the test the semen of the rams in group two was lower in prolactin, higher in LH and FSH than in the group one rams (B. D. Schanbacher and J. J. Ford, 1979).

Fertile estrus in the ewe depends on regression of corpora lutea in response to estrogen followed by ovulation. Injection of estradiol 17B, estrone or DES on day 10 or 11 of the estrous cycle were equally effective in reducing weight and progesterone content of corpora lutea.

An improved radioimmuno assay (RAI) was reported by D. A. Bolt (1981) for measuring ovine follicle stimulating hormone (FSH). Using this modified RIA, he reported that plasma FSH and LH rose 10 hours after estrus and increased four to six fold after ovariectomy. C. E. Rexroad (1981) reported that unfilled estradiol and progestogen binding sites in sheep endometrium cytoplasm peaked at days 5 and 9 of the estrous cycle, and in muscle at days 3 and 6, respectively.

Estrus was produced in lactating ewes by a silicone-progesterone-estradiol 17B implant 20 days post partum, followed by implant removal 12 days later and intramuscular injection of pregnant mare serum (PMS). Ewes that received 100 IU human chorionic gonadotropin (HCG) on days 12 and 13 postcoitus maintained 58 percent pregnancies vs 29 percent for untreated controls (R. J. Kittok, J. N. Stellflug, and S. R. Lowry, 1983).

Swine—In the economy of swine production an important factor is fecundity. The number of pigs weaned per liter is dependent on embryonic, fetal, and post-natal mortality as well as on the number of fertilized ova.

Reproduction of genetically obese, genetically lean, and conventional control sows, all restricted in feed intake (the ADG for the three sets were zero, one kilogram, and zero) from pregnancy day, 35 to 40 to parturition, resulted in reduced piglet birth weight; survival of piglets decreased in the litters of the obese line and the conventional (W. G. Pond et al., 1983).

In 1979, pig productivity was 7.2 pigs marketed per litter, and 1.8 litters per sow year, with a 1985 goal of 10 pigs marketed per litter, and 2 litters per sow year. R. J. Geritts stated that refinements in artificial insemination techniques and estrus-ovulation inducing compounds were necessary in order to achieve wide, successful use of AI in swine (R. J. Geritts et al., in Beltsville Symposium III, 1979, pp. 415-421).

A successful diluent for fresh boar semen (Beltsville L_1 or BL_1) developed by V. G. Pursel and his colleagues at Beltsville, contains glucose, sodium citrate, sodium bicarbonate, and potassium chloride. BL_1 diluent semen requires anaerobic storage (V. G. Pursel, L. A. Johnson, and L. L. Schulman, 1973).

Of the sperm of mammalian species, boar sperm is the most susceptible to cold shock. Cold sensitivity is associated with a high ratio of polyunsaturated fatty acids to saturated in sperm phospholipids and low cholesterol content of boar sperm membranes (V. G. Pursel, 1979). Butylated hydroxy toluene (BHT) preserved the fertilizing capacity of boar sperm despite 10 minutes cold shock at 0°C. The research team of Pursel and Johnson, in 1971, was one of three that fertilized sows' ova by intracervical insemination with frozen boar spermatozoa. All three teams used glycerol during freezing, and they stored semen as pellets frozen on the surface of dry ice and stored in liquid nitrogen. Egg yolk, low density lyoprotein, protects boar semen against cold shocks. Boar semen processed by the Beltsville system was used to inseminate sows at five locations, with 48 percent farrowing rate; the average litter farrowed was eight pigs (V. G. Pursel in Beltsville Symposium III, 1979, pp. 145-157).

Livestock and Poultry Waste Management

About 50 million tons of collectible fecal and urinary dry matter is voided by livestock and poultry annually. Odors and runoff pose pollution problems associated with feedlots and large scale poultry enterprises. Traditional use as fertilizer is still a principal and economic use within 10 miles of the point of origin. Processed and packaged wastes find extensive horticultural and garden use.

Much of the nitrogen (N) in manure is lost by runoff from storage piles and by runoff from fields after application. Georgia data indicate that N from broiler waste is utilized about 44 percent as efficiently as N from commercial fer-

tilizer. Fertilizer use of broiler manure 10 miles from point of origin was found to be competitive in value with commercial fertilizers (S. R. Wilkinson, ABR Report 254, ERS-USDA, 1979).

Feed use of animal waste is increasing, especially use of broiler and layer excreta for ruminants, which may efficiently use it for 15 percent or more of rations, especially to supplement nitrogen in corn and corn silage. Wastes should be processed prior to feed use to destroy pathogens. Drug residues in wastes are a potential hazard (Fontenot, Smith, and Sutton, 1983).

Dehydrated caged-broiler excreta and soybean meal were compared as dietary nitrogen sources for growing crossbred wethers. Rations containing 0, 7, 14 percent excreta were eaten readily; average daily gain (ADG) in the 8-week feeding trial was 194g, 195g and 178g, respectively. Digestibility of the organic matter in the three rations was the same—about 65 percent. Separate digestion trials with *excreta per se* gave true digestibility of excreta protein of 81 percent. (L. W. Smith and C. C. Calvert, 1976).

In very large dairy and poultry enterprises, methane production may be economical. Data on thermal properties of manure and manure slurries are essential to design of plants for dehydration or methane production. Specific heat and conductivity decrease as solid content of manure slurries increases. Net gas production is several-fold greater at 55°C than 35°C (Y. R. Chen, 1983).

IMPACT OF BAI RESEARCH

Research results produced by animal and poultry scientists in BAI and its successor entities are known, respected, and successfully applied throughout the United States and the world. The research of those scientists is highly regarded by their fellow scientists.

The impact of research done by them is partially measured by the frequency of citations of their work by other scientists. From 1965 to 1981, 432 animal and poultry scientists, either presently or formerly employed by BAI or its successor agencies, had research reports published in scientific journals. Their work was cited more than 40,000 times. (Science Citation Index, Part I, Citation Index, 11956-11981. Institute for Scientific Information. Philadelphia).

PROJECTIONS

Biological research will continue to be productive. Embryonic, fetal, and perinatal mortality cause heavy losses which appear to be controllable. Research can double the current efficiency of livestock and poultry production. Research has an established history of returning about 40 percent on funds invested in it. Consumers will benefit. They should; they pay for the research.

During the past century, consumer cost of beef has risen to twice (or more) the cost of poultry. Lamb is equally expensive. Pigs, chickens, turkeys, rabbits—with several or many offspring each year per female—have an inherent advantage over ruminants in cost of feed, investment, and care of the dam in proportion to that of each offspring. Under controlled or managed environments the yearly production per dam of two calves or lambs (or three for that matter) seems feasible. But they must be provided an environment in which they will survive to market weight.

General availability of computer facilities, and competence in their use, is producing many models for integrated animal production, marketing, processing, and distribution systems. Such systems must be validated by relevant, sufficient data in order for them to improve biological and economic efficiency of the animal and poultry industries. Concomitant with development and application of integrated systems is growth in scale, whether of individual, cooperative, or corporate livestock and poultry enterprises. The investment in environmentally controlled systems requires substantial capital. Efficient nonodorous waste management is an essential component in peopled areas. Experience in the United States and in Europe indicates that large-scale animal and poultry production enterprises induce people who operate or serve them to build nearby dwellings. Soon they begin to complain of noise, odor, and animal abuse.

Animal welfare demands humane and sensitive care for animals; research with laboratory animals benefits from it. Laboratory animal husbandry should become a recognized discipline as is laboratory animal medicine. Of primary importance is the use of laboratory animals as models—surrogates—for food animals; as for humans, this use requires, but does not receive, sophisticated and detailed comparisons of their metabolism, genetics, and behavior, for it must be remembered that while models may facilitate research; they cannot replace emperical data. Coturnix is not a chicken; rats

are not people; and rabbits are not ruminants.

Genetic engineering is currently popular. Important and spectacular achievements have been achieved—for example, the FMD vaccine produced at PIADL. However, since most important genetic traits involved in the improvement of food animals are of relatively low heritability (polygenic), equivalent achievements are not foreseeable in, for example, milk or egg production or fecundity. Heterosis is very important in commercial production. It cannot be assured by genetic engineering. In my opinion, support for breeding systems based on population genetics and heterosis should not be transferred to genetic engineering. Data banks should be assembled *and used*. Fantasy is, however, important. Jules Verne opined: "What the mind of man can imagine, some man will do." Argument over potential irresponsible use of genetic engineering will continue.

In the past, research in animal and poultry science, husbandry, has resulted, through its application as technology, in abundant supplies of meat, milk, and eggs for consumers at relatively diminishing costs. Research can continue to do so. Investments in the form of people, educated and trained in the relevant basic sciences and in the arts of husbandry, are needed in continuously replenished supply. Those knowledgable of food animals and their habits, needs, and preferences are in very short supply. Research is done by people of all ages, but there is no substitute for the freshness and vigor and curiosity of youth.

Many clinical nutritionists and public and private food and health agencies advocate restriction of caloric intake of fats to 30 percent or less of total human caloric intake. Most of them emphasize restriction of saturated "hard" fats and associated cholesterol from meat, milk, and eggs. It has not been demonstrated that people who follow such dietary regimens live longer or are more healthy than those who do not, with the exception of persons with genetically high blood cholesterol levels.

Further research in human nutrition in relation to obesity, heart disease, and cancer, in relation to quantity and saturation of dietary fat ingestion and of dietary cholesterol intake and metabolism, may influence future research emphasis on content of these nutrients in meat, milk, and eggs. It is likely that scientists and food industries and agencies who have recommended use of polyunsaturated fats in excess of established requirements will not recant, but quietly cease such advocacy.

Pig fat and milk fat percentages respond readily to genetic selection. Beef fat can be reduced by shifting from steer beef to bull beef; young bulls gain as fast in feedlots without use of growth promotant chemicals in their feed as steers do with growth promotants. Bull beef is leaner than steer beef. Four-pound broiler carcasses contain about 13 percent fat; 2-pound carcasses, about 4 percent, although life-cycle feed efficiency and processing costs favor the 4-pound carcass; so does flavor.

Will consumer preference and associated market demand in the future be guided by nutritional requirements or appetite? Animal science can and (probably) will modify meat, milk, and eggs in conformity to market demand.

Inclusion of economists, sociologists, psychologists, biologists, engineers, and mathematicians in interdisciplinary basic research to gain an understanding of the nature and nurture of whole animals and of animal-human-environmental ecosystems are likely to be productive. Least-cost socially and environmentally acceptable systems may be as important as biological efficiency. If livestock producers, processors, distributors, and consumers are to receive equitable benefits from the applications of results in animal and poultry science and husbandry, there must be greatly increased communication and understanding among animal and poultry scientists and their peers in the social sciences and the humanities. Basic research is designed to achieve understanding, but all the concepts, proven theories, and practices will not achieve public understanding without communication—telling and listening, and reflection.

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PART IV
ANIMAL PARASITOLOGY
IN THE
UNITED STATES DEPARTMENT OF AGRICULTURE
1886-1984

By
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What is animal parasitology? Animal parasitology is a specialized branch of biology that may be defined as the study of the relationship between animal parasites and the animal hosts in or on which they live and from which they obtain their nourishment. These parasites are all about us: They parasitize house flies, mosquitoes, ticks, fish, shellfish, dogs, cats, poultry, and other domestic and wild animals, including man. Scarcely any animal on the face of the earth does not have its quota of parasites. Animal parasitology is largely an amalgamation of protozoology (the scientific study of one-celled animals including amoebae, anaplasms, coccidia, piroplasma, plasmodia—malarial organisms-spirochetes, and trypanosomes), helminthology (study of worms—both round and flat—including tapeworms and trematodes or flukes), entomology (study of insects), and acarology (study of mites and ticks), but does not include the free-living species within these life forms.

The Department of Agriculture is interested in the study of animal parasites and in development of methods for their control because of the economic losses that occur when they are allowed to multiply unchecked in food-producing animals and other livestock including household pets. Furthermore, many animal parasites are transmissible to and cause disease in man. The identification of parasites, the method of infection, the pathology caused by the parasite, and the development of methods for preventing infection and for removing parasites from their hosts—all are important concerns of both veterinary and human medicine.

EARLY YEARS

Programs and People

Daniel B. Salmon, a graduate of the Cornell University Veterinary Medical College, was called to Washington, DC, in 1883 to establish a Veterinary Division in the Department of Agriculture. He set up a laboratory and built an experiment station on Benning Road, N.E., in the outskirts of Washington, and there some of the early research on parasites was done. These facilities were the beginning of the future Division of Pathology of the Bureau of Animal Industry.

The Bureau of Animal Industry (BAI), with Dr. Salmon as chief, was established on May 29, 1884. Three graduates of the Cornell University Veterinary Medical College became its first staff members. Dr. Theobald Smith in 1884 was appointed an inspector and placed in charge of investigations on infectious diseases. Dr. Fred L. Kilborne joined the BAI in 1885, and Dr. Cooper Curtice, the BAI's first veterinary parasitologist, came in 1886. His primary interest was the welfare of "The dear cow, the dear sheep and the dear horse."

By 1891, the volume and variety of the work of the BAI had increased until it could no longer be supervised by one man, so on April 1, 1891, four divisions were formed within the Bureau. Research on animal parasites was separated from investigations of bacterial, viral, and fungal diseases of livestock and was given the title "Zoological Laboratory" within the newly created Division of Animal Pathology. Dr. Albert Hassall, an English veterinarian, educated in private schools and at the Royal Veterinary College in London, had been appointed veterinary inspector in 1887 and stationed in Baltimore, MD. On April 30, 1890, he entered veterinary practice in Baltimore, but the influence of Dr. T. Spencer Cobbold, one of his professors and England's most distinguished parasitologist, was so profound that he

decided to become involved in parasite research. He was then brought to Washington in March 1891 and assigned to duty in the Zoological Laboratory as an assistant zoologist.

When Dr. Curtice discovered that he was going to have to report to his friend and roommate, Dr. Smith, who would be his supervisor under the new organization plan, he, who had described himself as, "ever of a rebellious nature," abruptly resigned from BAI in May 1891. In June, Charles Wardell Stiles, having received his A.M. and Ph.D. degrees from the University of Leipzig, Germany, was appointed assistant in charge of the Zoological Laboratory. Continued expansion of the Bureau's responsibilities led, in August 1891, to moving the Zoological Laboratory, along with the other divisions of the BAI that were engaged in laboratory work, from the main Agriculture Department building on the Mall, to nearby 1362 B Street, S.W., where more room for expansion was available.

Louise Tayler, a scientific assistant, of Youngstown, OH, was appointed to the Pathological Division of the BAI in 1887, and in August 1900 was assigned to the Zoological Division along with Eunice R. Oberly, who was appointed clerk. On August 5, 1902, Dr. Stiles transferred to the Hygienic Laboratory of the U.S. Public Health Service as chief of the laboratory, but he continued supervision of the Zoological Laboratory until June 1, 1903. He never completely severed connections with the Zoological Laboratory and maintained a close relationship with it for many years. In 1903, Brayton Howard Ransom became scientific assistant, in charge of the Zoological Laboratory. He had studied parasitology under Henry B. Ward of the University of Nebraska, and like so many of Dr. Ward's students of later years, became a research parasitologist in the BAI.

The Zoological Laboratory was officially recognized as the Zoological Division in 1906, with Dr. Ransom as its first chief. Maurice C. Hall, another student of Dr. Ward's, and destined to become the next chief, joined the division in 1907. According to Benjamin Schwartz, division chief (1936-1953), Dr. Hall, "having more than mere enthusiasm of youth, coupled with a tremendous capacity for hard work and sustained interest and effort, became deeply engrossed in the slightly explored field of veterinary parasitology."

The following poem is an example of the poetic ability of Dr. Hall, then assistant chief of the Zoological Division:

"Nematode, nematode,
Wilt thou be mine?
You shall not live in horses,
Or cattle, or swine,
But feed upon roses
and lilies so white,
And have a new Latin name
Every third night."

This poem was a place-card verse written in 1922 for N. A. Cobb, head of the Office of Nematology, Bureau of Plant Industry, USDA, gently chiding him about errors in naming parasitic worms of plants, which he occasionally made and which greatly disturbed Dr. Hassall because he had to classify the "beasts." The east wing of the new Agriculture Department building on the Mall was completed in 1908, and after 17 years on B Street, S.W., the laboratories of the Zoological Division were moved to the new building. The division occupied about one-third of the second floor.

Howard Crawley was the first protozoologist of the Zoological Division. During the last few years of his career in the division, Mr. Crawley studied the size variation of helminth eggs as a basis for diagnosis of specific helminthiases in domesticated animals and poultry. It was during this period that he seemed to have some difficulty at lunch time distinguishing between beakers containing helminth eggs and the beaker containing the beverage that was to be consumed with his lunch. According to reliable witnesses, he was often observed to sip absent-mindedly from the potentially lethal container. In spite of this practice he thrived in the division until 1919, when he resigned to accept a position as parasitologist with the Pennsylvania Bureau of Animal Industry in Philadelphia.

Lawrence Avery, an Englishman, after completing a period of service with the U.S. Navy as a medical illustrator, began his long career with the BAI and the Zoological Division when, in 1914, he was appointed laboratory technician.

Benjamin Schwartz, who had been a child immigrant from Austria-Hungary, and who was destined to be the last and longest-tenured chief of the Zoological Division, joined the division as a junior zoologist in 1915.

In 1917, Dr. Hall resigned from government service to accept a position as research parasitologist at Parke, Davis & Company, a pharmaceutical firm. After a tour of duty with the newly organized Veterinary Corps of the U.S. Army, however, he returned to the BAI in 1919 and was appointed a senior zoologist and assistant chief, and finally, chief of the Zoological Division. In 1920, Eloise B. Cram became the second female research scientist to join the Zoological Division. In December of that year, Dr. Schwartz resigned to accept a position as professor of parasitology at the University of the Phillippines.

The fortieth birthday anniversary of the Bureau of Animal Industry was celebrated in 1924. The Zoological Division still occupied the second floor of the east wing of the new Agriculture Department building. Over the years the Zoological Division had become recognized as the center of veterinary parasitological research in the United States and was visited by scientists and laymen from all over the world who were seeking the latest information on the parasites and parasitic diseases of animals and man—information that was not readily available anywhere except perhaps at the London School of Hygiene and Tropical Medicine in England.

All employees of the Zoological Division were saddened by the untimely death of Dr. Ransom on September 17, 1925, prematurely ending a brilliant scientific career at the age of 46. According to Dr. Hall, Dr. Ransom, in his short career, had attained the scientific stature comparable to the illustrious French parasitologist, Professor Alcide Railliet of the Veterinary School at Alfort, then in his seventies. Dr. Hall named the following among Dr. Ransom's major contributions to science: "His monographic systematic work on parasites, (i.e. his comprehensive reviews of parasite identification and classification systems); discovery of many of the most economically important parasites; contributions to the understanding of the basis of parasite-induced pathology; development of measures for controlling stomach worms in sheep; development of the McLean County System of Swine Sanitation; research that formed the basic regulations of the U.S. Department of Agriculture for the control of trichinae and cysticerci; and establishment of the fundamental rationale for cattle tick control by dipping." Dr. Hall concluded, "It is a great tribute to Dr. Ransom's scientific achievements that despite his extensive and highly important contributions to parasitology and medical zoology covering a quarter of a century, none of his major scientific work has ever been challenged." Dr. Hall was appointed chief of the Zoological Division and Dr. Hassall, assistant chief, on October 1, 1925.

In December 1925, the BAI announced plans to extend its veterinary work to include more fully the application of the results of research to the management of stock on farms. Projects on the control of roundworms of swine and stomach worms of sheep were to be included in the expanded animal husbandry program with a view to extending the beneficial methods developed by the Bureau's other specialists. To provide facilities essential to this program the Bureau leased 1,063 acres of additional land adjacent to the Beltsville farm.

Among the noteworthy activities relating to parasitology that occurred in 1926 were the establishment of the B. H. Ransom Memorial Trust Fund as a memorial to the late Dr. Ransom, and the designation of the September 1926 issue of *The Journal of Parasitology* as the Ransom Memorial Number.

In 1926, Dr. Hall was asked to make a survey of the parasites of livestock and other animals in Central America for the Bureau of Animal Industry. He spent three months in Central America and collected parasites at abattoirs in Panama, Grenada, Nicaragua, and El Savador. He also treated selected human population groups for the removal of hookworms, with the new anthelmintic, tetrachlorethylene, with excellent results. From his study of the parasites of food producing animals in Central America, Dr. Hall concluded that there was slight danger to the livestock industry of the United States from infection with the internal parasites of Central American livestock.

The year 1926 marked the conclusion of highly successful experiments on the control of sheep and swine parasites in the Northern and Central States and the beginning of similar work in the South as there was mounting evidence that parasites were causing serious losses to the livestock industry in that part of the country.

In 1927, the Zoological Division was conducting research at five locations outside the Washington, DC, area: zoological investigations relating to meat inspection and the internal parasites of swine, at Chicago, IL; investigations on external parasites at Kansas City, KS; swine parasite control work at Moultrie, GA; investigations of the internal parasites of sheep at McNeill, MS; and investigations of the internal parasites of cattle at Jeanerette, LA (Powell, 1927).

Two new employees joined the Zoological Division in 1927 and were assigned to the research projects indicated:

Myrna Frances Jones, M.S. - Junior Zoologist. Life Histories and Morphology of Poultry Tapeworms, Washington, DC, Ph.D. (1932).

Glenwood C. Roe, M.S. - Junior Zoologist. Parasite Classification and Distribution Unit, Washington, DC.

Dr. Raffensperger was transferred from McLean County, IL, to Miles City, MT, to take charge of the horse parasite investigations to be conducted there. Dr. Hall reorganized the division's projects in 1928, putting them in groups according to host animal species, as follows: Parasites of Poultry, Parasites of Swine, Parasites of Ruminants, Parasites of Horses, Miscellaneous Parasites, Treatments for Internal and External Parasites, The Index-Catalogue of Medical and Veterinary Zoology, and the Parasite Collections.

He also expanded the research program of the division in 1928 and added 11 new employees. Of these, Vincent B. Lynch and Demetrius T. Sinitsin deserve special mention. Both men were in dire straits financially. Professor Lynch had recently retired from his position as professor of biology and affiliated sciences at the U.S. College of Veterinary Surgeons, Washington, DC, but his retirement pay was not sufficient to sustain him even though he lived in very modest circumstances. Dr. Sinitsin was a Russian parasitologist who, since his arrival in the United States in 1923 shortly after the Russian revolution, had been unable to find work other than at menial tasks. When Dr. Hall learned of the possible contributions that both men could make to the division's research program he appointed them to positions in the division, thereby giving them a chance to again become productive members of society.

Beltsville and Beyond

The Zoological Division in 1928 had no field station of its own in the Washington, DC, area. Its Washington research was limited to studies on the taxonomy and classification of parasites, to experiments with small laboratory animals and with arthropod, annelid, and molluscan intermediate host of parasites, and to experiments with parasites of animals that could be housed in the animal room, which was on the fourth floor of the east wing of the Agriculture Department Building. When it was necessary to do research with large farm animals, it could be done only at the Beltsville, MD, farm of the Animal Husbandry Division of the Bureau, the Animal Disease Station a Bethesda, MD, at other field stations of the Bureau, or in cooperation with farmers who would allow their animals to be used in experiments conducted under direction of research scientists of the Zoological Division.

This last-mentioned arrangement was not all bad as it resulted in the development of the first practical method for controlling infection of piglets with the large intestinal roundworm of swine, *Ascaris suum*, but none of these ways of doing parasite research was entirely free of difficulties.

Early in 1929, Dr. Hall told John R. Mohler, Chief of the Bureau of Animal Industry, that he would like to establish a field station where the Zoological Division could conduct research on the parasitic diseases of large animals and poultry, including wildlife. In this facility experimental work would be performed under conditions similar to those existing on farms and in nature, and, at the same time, be subjected to tighter controls than would be possible under ordinary field conditions. Furthermore the results of successful parasite control experiments could be applied to actual farm conditions with little or no modification. The research scientists would also be free to perform necropsies on their experimental animals whenever the protocol of the experiment demanded it. Dr. Hall indicated that he would like to have the new station located in the Washington, DC, area so that the scientific staff would have access to the excellent library facilities available in the immediate vicinity.

In response to Dr. Hall's request, Dr. Mohler allotted to the Zoological Division about 30 acres of land on the Animal Husbandry Division's section of the government-owned farm near Beltsville, MD. In his letter to Dr. Dunlap, of the Agriculture Secretary's Office, he suggested that the area allotted to the Zoological Division be located on 10 acres of new land on the north side of the farm, about one-half mile from the poultry line. This area had access to the Old Annapolis Road. He also suggested that an additional area of approximately 20 acres would be needed to accommodate the animals that would be kept there for experimental purposes. He mentioned that the area would be fenced and cross-fenced for the purpose of handling the new animal population, and that a one-story building 40 by 50 feet, with a basement and gable roof, would be erected on the site. He noted that the cost would be about $6,358.00, the expense to be borne by the Zoological Division, but the construction would be in cooperation with the Animal Husbandry Division, which would actually do the work.

The tract included a small elevation, called "Chinquapin Hill" by local residents, and the area immediately surrounding

it. A condemned county road ran just east of the hill. Most of the tract was covered with second-growth timber. Further east was a small pond, the water-filled entrance to an abandoned iron mine that had been operational in pre-American Revolution times. The pond could be used for experiments with waterfowl and as a source of amphibious and aquatic intermediate hosts of animal parasites. The area had not been used for pasturing livestock for many years and would provide a parasite-free environment for experimental animals. However, it had the disadvantage of requiring extensive tree clearing and road construction before it could be fully utilized.

Road building, land clearing, and fencing of feed lots and pasture at this site near Beltsville went on apace during the remainder of 1929, with the cooperation of E. W. Sheets and Ben Brandon of the Animal Husbandry Division. Many of the division's scientists in Washington, DC, were critical of the site.

Some felt that it was foolhardy to attempt to build an experiment station in such wilderness area. Others objected to spending the time, effort, and money to clear the area of trees when there was plenty arable land in the immediate vicinity that could have been set aside for the new facility. The new station was often referred to as "Hall's Folly". Although some of this criticism may have been justified, much of it came from employees who were comfortably situated in Washington or in Virginia and didn't want to travel the additional 17 miles (34 miles round-trip) out into the Maryland countryside to conduct their research.

In his annual report to the BAI Chief in June 1929, Dr. Hall reported, "Previous lines of work on worm parasites of poultry were continued and investigations of protozoan parasites, suspended for several years were renewed." He also summarized the results of research projects conducted by the division outside Washington, DC, on cattle grub control in Knox County, IL, and Prowers County, CO; horse parasites at Lexington, KY, and in Montana; swine parasites at Moultrie, GA; sheep parasites at McNeill, MS; liver flukes of ruminants in California; and anaplasmosis at Jeanerette, LA.

Key personnel changes occurred in 1929. Ena A. Allen, poultry protozoologist, arrived from California; Lawrence Avery was transferred from the Tuberculosis Eradication Division of BAI to be the administrative officer for the new field station of the Zoological Division at Beltsville; and Dr. Gerard Dikmans was transferred from Jeanerette, LA, to Washington to be head of research on the internal parasites of ruminants.

A nationwide civil service examination in veterinary parasitology was held in October 1929 to establish a list of eligible candidates from which Dr. Hall hoped to pick qualified people to staff the new laboratory. In addition to taking the examination, the applicant was required to submit a thesis on a parasitological project he or she had conducted as a graduate student or to furnish other proof showing additional experience in the field. Other BAI divisions were also canvassed for possible candidates.

The examination and transfers from other units of the Government service resulted in the appointment of several new employees to the scientific and support staffs of the Zoological Division. Very soon after they had arrived at the division headquarters on July 1, 1930, had pledged allegiance to the flag of the United States, and had received their assignments, they were gently reminded by Dr. Hall that the slightest suggestion or request related to their work, coming from him or from their immediate superiors, carried the force of a military order and was to be obeyed without question.

Occupation of the New Laboratory—By January 1, 1930, bare hillsides, new roads and partially fenced feedlots and pastures gave the area allotted to the Zoological Division for its new field station a "soon-to-be-occupied" appearance. The roads were named for personnel of the Bureau of Animal Industry who were responsible for establishing veterinary medical and parasitological research in the Department of Agriculture, or had made substantial contributions to knowledge in these disciplines.

Construction of the first laboratory building was begun in February 1930 with farm labor supplied by the Animal Husbandry Division. At the suggestion of Dr. Hall, Lawrence Avery, general superintendent of construction of the new facility, obtained a ship's mast from the Navy surplus property office, and had it placed on the highest point of Chinquapin Hill for use as a flag pole. On February 25th, while the foundation of the laboratory was still being laid, Dr. Hall made a special trip from his office in Washington to Beltsville to personally raise the "Stars and Stripes" to the top of the mast and officially claim the area for the Zoological Division.

John R. Mohler, in his annual report of the Bureau of Animal Industry to the Secretary of Agriculture, dated June 30,

1930, stated: "A noteworthy development of the year was the establishment at Beltsville, MD, of a small experiment station for studies of animal parasites. . . ." Dr. Hall elaborated on Dr. Mohler's announcement, stating that the new facility was ". . . the most important development of the year, from the standpoint of the broad field of parasitology as a whole. . ." and that at that time the station had a temporary building and 5 acres of cleared land, of which 4 were in pasture.

First "temporary" animal parasite research laboratory of the Zoological Division, BAI, at Beltsville, Maryland (1930). Dr. Lawrence Avery, administrative officer, at door; this author, in window. Note absence of roads.

Dr. Hall, as president of the American Veterinary Medical Association in 1930, and in demand as a speaker at A.V.M.A. meetings, was able, through his eloquence and thorough knowledge of parasitology, to bring to his audiences a new appreciation of the importance of parasitological research in both human and veterinary medicine.

Since the new laboratory at Beltsville was not yet ready for occupancy, Dr. Underwood, John Lucker, and John Andrews[1] spent their first few months in Washington familiarizing themselves with the scientific literature pertaining to their assigned research projects. This work was greatly facilitated by Miss Florence Thompson, a librarian from the main Agriculture library, who made it her business to know the research problem of each scientist and brought to his desk the current books and journal articles she believed would be of particular interest to him. This service saved many hours of library work that could be used for reading, writing, or experimental work.

The new employees were also privileged to examine a great variety of animals for parasites. Animals dying at the National Zoo were sent routinely to the Zoological Division for parasitological examination. I spent much of my first 3 months in the Zoological Division retrieving parasites from rodent viscera that had been sent to the division from different parts of the United States by the Bureau of Biological Survey to provide material for Dr. Dikman's study of the nematode parasites of these animals. Mr. Lucker investigated the life history of the gullet worm of swine, *Gonglyonema pulchrum*, and Dr. Underwood assisted Willard H. Wright, who had joined the division in 1928, with his anthelmintic research. At frequent intervals all members of the scientific and technical staff who could be spared from other duties were called upon to help with the parasitological examination of sheep and cattle slaughtered at the Animal Husbandry Division abattoir on the Beltsville farm.

Planting the Flag—The Zoological Division's first laboratory at Beltsville was finished in the early fall of 1930. On learning that the building was about to be completed, Dr. Mohler, Bureau Chief, informed Dr. Hall that it was incumbent upon him to have it occupied as soon as possible to show that it was urgently needed in the division's research program. This action was necessary at the time because the Great Depression of the 1930's had begun to rear its ugly head and appropriations for new construction were difficult to justify.

On November 11, 1930, I received a letter from C. C. Carroll, business manager of BAI, stating, "You are ordered to report to Beltsville November 17, 1930." However, because of the lack of a functional heating system in the new building and "the coldest weather in 58 years," the order was not complied with until early in December when Paul C. Underwood and I were sent out to occupy the building.

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[1]By editorial decision, first-person pronouns are used hereafter, whenever appropriate, in reference to Dr. John Andrews, author of this section.

There were no animals and very little scientific equipment at the new laboratory during the first few weeks of its existence, so we "pioneers" were somewhat hampered in carrying out our assignments. Dr. Underwood and I were issued ancient monocular microscopes and antiquated microscope lamps. I also was issued a camera lucida to assist in making accurate drawings of the larvae of sheep nematodes. Also available were drawing paper, eggs of sheep parasites (which I personally removed from animals slaughtered at local abattoirs), sheep manure, charcoal, culture dishes, a sterilizer, an incubator, a Baermann apparatus for separating larvae from material in which they were cultured, and a typewriter.

Dr. Underwood had to do his anthelmintic experiments, involving the removal of internal parasites from horses, with animals kept at the Animal Disease Station (BAI) at Bethesda, MD, or with horses borrowed from a rendering plant near Four Mile Run, VA. The division paid $5.00 for each horse it obtained from the rendering plant and when the experiments were concluded returned the horse to the rendering plant for disposal.

When not otherwise engaged, Dr. Underwood and I were able to keep ourselves busy at Beltsville by repairing, sanding, and refinishing the office furniture obtained for us by Dr. Avery from a U.S. Government surplus equipment warehouse. We also helped Dr. Avery with housekeeping chores. And Dr. Underwood's expertise with recalcitrant timepieces kept the station clocks humming on time. We often spent 2 or 3 days a week in the division office in Washington, where we attempted to keep abreast of the current scientific literature and to take care of experiments we had started during a previous visit. With the holiday season interrupting our work schedule, we accomplished little more during the last days of 1930 than to realize our major objective: occupation of the new Beltsville Parasite Laboratory.

Getting There. . .and Back—The Bureau had purchased a bus before 1930 for its hog cholera control program. The seats were ripped out and the bus was used to haul pigs. When it was no longer needed for that program, the evidence literally was shoveled out, the interior was hosed down, the seats were replaced, and the bus was put into service shuttling Agriculture employees and official visitors between the Agriculture Department downtown and the Beltsville farm, free of charge. The bus was large enough to accommodate all the employees who worked on the Beltsville farm, including those of the Animal Husbandry Division, with plenty of seats to spare. Edwin White (Whitey), the driver, began the trip to Beltsville promptly at 7:55 a.m. each work-day morning (Monday through Saturday). Starting at the Agriculture Department building, and with occasional stops to pick up passengers, the bus went north on 12th Street N.W., to Rhode Island Avenue, then northeast on Rhode Island Avenue to Washington-Baltimore Boulevard (U.S. 1), north to Powder Mill Road, east through the main gate of Beltsville farm to Poultry Road, and north to the bus terminal in the poultry husbandry section. Passengers going on to the new Animal Parasite Laboratory had to hitch a ride in another vehicle or walk a quarter of a mile, climb a steep hill, and traverse a heavily wooded area to get to their destination.

I have never forgotten one walk up this hill on a very rainy day. My loose-fitting overshoes stuck in the mud at every step and would come off. The bag of oranges I was carrying along with books, papers, etc., became very wet. Every time I reached down to replace an overshoe, an orange would fall out of the dissolving bag and I would have to pick it up before I could take the next precarious step. This, of course, resulted in the other shoe's being stuck in the mud, followed by its replacement and the loss and recovery of another orange. I have often thought how amusing that episode might have been to an appreciative observer.

At the end of the work day (4:30 p.m., Monday through Friday, noon on Saturday), the bus made a return trip from the Beltsville terminal to the Agriculture Building in Washington, making frequent stops along the way to discharge passengers.

A small Government-owned bus made the round trip between Beltsville and the Agriculture Department at noon, Monday through Friday, to carry the mail and incidentally to provide free transportation for employees and official visitors who had to make the trip at midday. Occasionally the little bus was used to ferry employees between the parasite laboratory and the bus terminal on the farm, until it was accidentally wrecked on a tree stump. After that, everybody walked both ways.

Riding the large shuttle bus occasionally was hazardous. One cold winter morning, when the roads were coated with ice, the loaded bus began to skid on Rhode Island Avenue near First Street, N.E., and didn't stop until it reached Fifth Street. As the passengers became concerned for their personal safety, they left the bus by the front door, one by one, leaving the driver to finish the skid all by himself. When the bus came to a stop, everyone got back on and continued the trip to Beltsville as though nothing unusual had happened.

If a Beltsville employee of the Zoological Division missed the bus and had no other means of transportation, he still could get to work via the interurban streetcar line that terminated at Boteler's Store (still operating in 1986) in Beltsville or via commercial bus. But he would still have 2 miles to walk before reaching the parasite laboratory. By special arrangement, visitors, and occasionally employees, were met at Beltsville and taken to the laboratory in privately owned cars of employees or in one of the Government-owned vehicles. Return trips also could be arranged.

The Pace Quickens—The year 1931 ushered in a period of greatly increased activity at the new Beltsville laboratory. A pesticide testing laboratory was built by the Zoological Division for the Food and Drug Administration east of its main building. Seven men were added to the labor force.

Facilities for housing animals at the Beltsville laboratory in the early part of 1931 were minimal and poultry parasite work was housed temporarily in the poultry husbandry section of the Animal Husbandry Division's farm. Because of the difficulty of carrying on animal experimentation at Beltsville without animals, the research scientists stationed there still found time to repair and refinish their office and laboratory furniture. They also helped prepare the laboratory floors for painting and responded to such emergencies as pulling trucks out of mud holes and fighting forest fires in neighboring woods. Occasionally they brought work from Washington that required their undivided attention, knowing that they would not be disturbed by visitors. During the lunch hour, they were able to relax. Weather permitting, they pitched horseshoes (retrieved from an old dump on the premises), often ate lunch down by the pond and flavored their sandwiches with wild onions growing in the immediate vicinity, and went swimming in the pond *au naturel* when the work load and degree of isolation permitted.

In 1931, for the first time a member of the scientific staff, Benjamin Schwartz, was designated to work with personnel of the Agriculture Extension Service, which was cooperating with the Zoological Division in carrying out large-scale programs for the control of parasites of horses, sheep, and swine in regions of the United States where the problems were occurring.

The appointment of Sevillion B. Drury as clerk and administrative assistant to Dr. Avery on July 1, 1931, marked the recognition of the Beltsville laboratory as an autonomous unit of the Zoological Division. It now had its own administrative office, a full-time research staff of four scientists, and a labor force of nine men, with eight more to be added before the year was out.

The year 1932 also was eventful in the history of the Zoological Division. Dr. Hall had the entire scientific staff gathering information for "Treatise on Veterinary Parasitology," the first volume of its kind to have its origin in the United States. All research personnel in the division, in addition to their regular duties, began preparing accurate drawings of animal parasites, writing detailed descriptions of the parasites and the diseases caused by them, and collecting information on their geographical distribution and methods for their control and eradication.

The year 1932 also was eventful for Government employees because of the deepening economic depression. They were forced to take a month's vacation without pay and were later given an across-the-board salary cut of 15 percent. No longer could both husband and wife work in the Federal service. Employees at Beltsville who had been using the Government bus to come to work discovered suddenly that they no longer had free transportation because of a disagreement between two of the bureaus regarding financial arrangements to keep the bus running. The problem was solved by (1) using one's own automobile, (2) carpooling, (3) bicycling, or (4) paying a fellow worker for a ride to and from the farm.

The building program at Beltsville continued at a much faster pace in 1932. Stalls for horses were built in the new barn with one room reserved for poultry parasite work. The pesticide testing laboratory was completed, and a night watchman was hired to safeguard construction materials and other equipment. Isolation pens for sheep and animal shelters for feedlots and pastures were constructed. Grass plots were planted to study the behavior of sheep nematode parasite larvae on pastures, and the first incinerator was built for disposal of animal carcasses and other refuse. Screens were installed in the laboratory and barn windows and during the last 6 months of 1932, a barn and laboratory were built for study of arthropodborne parasitic diseases on the blood of cattle.

Dr. Hassall was forced to retire at the end of 1932 because of a provision in the Economy Act that all Government employees who by reason of age and length of service were eligible to retire could not be kept on the payroll after July 1, 1932. Dr. Hassall retired, but continued to work on the Index-Catalog two days a week without pay. His devotion resulted in considerable notice in the press and presented the personnel branch of the Bureau with the unique

problem of determining how to handle a former employee who insisted on working, although not legally part of the work force. In July 1934 he was given the title *collaborator* so he might have official status in the bureau and to permit publication under his name of the Author Index of the Index-Catalog of Medical and Veterinary Zoology, which was being reissued.

Dr. Hassall died in 1942 of a heart attack at the age of 80 and was buried in an unmarked grave in the churchyard of an Episcopal church just east of Bowie, MD. As an unusual example of employee friendship, respect, or just plain human kindness, the following incident deserves a place in history. In the early 1970's Miss Mildred A. Doss, a retired librarian and coworker with Dr. Hassall, provided a headstone identifying the grave. She was assisted by Mr. Bowie, caretaker of the cemetery, Dr. J. Ralph Lichtenfels, head of the Parasite Classification and Distribution Unit of the Animal Parasitology Institute, who helped place the headstone, and another friend and coworker, Miss Marion M. Farr.

Programs Increase

In May 1933, the new action programs of the Department of Agriculture were launched with the organization of the Agricultural Adjustment Administration to help farmers cope with the economic depression that still gripped the country. Dr. Schwartz was detailed to help States that were interested in organizing and conducting parasite control work. On July 1, activities in the Beltsville area were organizationally brought together in the Agricultural Research Center. Funds for the division's Parasite Research Laboratory were increased. In October 1933, with additional funds available through the Public Works Administration (PWA) and supplementary manpower from the three Civilian Conservation Corps camps in the Beltsville area, work could now be accelerated on the deforestation and construction projects. The first sign identifying the site of the parasite laboratory as belonging to the Zoological Division was put up in 1933 and road signs appeared at strategic turns in the road giving directions to the laboratory.

Also in 1933, plans were drawn up for a main building designed to provide more laboratory space, offices for administrative and clerical personnel, a library, and conference room; for laboratory buildings for specialized research on parasitic diseases of livestock and poultry; for barns and field shelters to house the animals used in the experiments; and for facilities to raise the dogs needed for anthelmintic and dog heartworm research. These facilities were needed to enable researchers to raise their own dogs in an effort to standardize the size, weight, and temperament of the dogs used for the type of experiment in which they would be used. Furthermore, the Society for the Prevention of Cruelty to Animals was objecting to the policy of providing animals to laboratories for experimental work.

Forty-three acres were added to the original 30-acre tract at Beltsville in 1934. The first section of the main laboratory and administration building was completed and dedicated. Most of the specialized laboratories and accessory buildings were also completed and furnished with shelves, benches, tables, chairs, and laboratory equipment needed for an expanded research program.

The following account of the dedication was taken from the *Journal of the American Veterinary Medical Association*:

> The new Zoological Building at the Beltsville Research Center, Beltsville, MD, was dedicated on October 20, 1934, in the presence of more than 100 guests prominent in the fields of Zoology and allied sciences. Dr. Maurice C. Hall, Chief of the Zoological Division of the U.S. Bureau of Animal Industry, presided and several guests gave short talks. The speakers included: Dr. Cooper Curtice, who was the first Chief of the Division; Dr. Charles Wardell Stiles, who also served as Chief of the Division; and Dr. Albert Hassall, who until his recent retirement, was Assistant Chief. They discussed the early work of the Bureau in research and procedures for the eradication and control of animal parasites, and stressed the possibilities that the new building and equipment provide for additional investigations.
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> Appearing on the program also were: Dr. Henry B. Ward, permanent secretary of the American Association for the Advancement of Science; Dr. W. E. Cotton, Superintendent of the Bureau of Animal Industry Experiment Station at Bethesda, MD; Dr. Lawrence Avery, a superintendent of the new laboratory and Earl C. Butterfield, newly appointed superintendent of the Beltsville Research Center. Other guests represented Johns Hopkins University, The Helminthological Society of Washington, the Smithsonian Institution, and various branches of the Department of Agriculture.
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> The building cost $50,000 and contains 31 rooms. It will be used for experimental work in the control and eradication of parasites. Several other buildings accommodate small animals such as dogs, cats, guinea

pigs, rabbits, chickens, pigs and others. The special equipment includes a variety of apparatus, a postmortem room, refrigerator room, incinerator and library. The lots and pens outside these buildings are separated by double fences and ditches to prevent contamination from other pens. Special equipment is provided also for the disposal of manure from pens where parasitized animals are being kept. There are also small oil moats, in some cases, to insure isolation of animals in certain types of experiments. The laboratory building and other small buildings were designed by Dr. Lawrence Avery, who also planned the landscaping of the adjacent grounds in such a way as to utilize as much of the native shrubbery as possible. A ravine which lies at some distance from the buildings has been utilized by simulating a zoological park with pens and shelters for dogs that will be kept for experimental purposes.

The Bankhead-Jones Act—A most important event for parasitology in the Department of Agriculture was the passage of the Bankhead-Jones Act in 1935, which provided a special research fund for the study of animal diseases and parasites to be carried on by the U.S. Department of Agriculture in cooperation with the State agriculture experiment stations. The act enabled the Zoological Division to expand its research activities concerned with ". . . the mechanism of infection with parasites, utilizing for this purpose economically important protozoa, flukes, tapeworms, roundworms, or such other parasites of domestic animals and poultry, as may be of economic importance, with a view to developing more adequate control methods than are now available."

Eloise Cram spent 3 months at the U.S. Agriculture Department's station at Mayaguez, Puerto Rico, in 1935, studying parasites of poultry and game birds under the auspices of the Office of Experiment Stations, and Dr. Hall went to Hawaii for 2 months to study the parasites of livestock in that part of the world, in cooperation with the Hawaii Agricultural Experiment Station, the University of Hawaii, the Territorial Veterinary Office, and the Territorial Board of Health. Money also became available for improving the appearance of buildings at Beltsville.

Recognition and Change—Early in 1936, Dr. Hall's skilled literary craftsmanship was recognized by the selection of his paper entitled, "Romantic Government Versus Unromantic Government," for inclusion in a book entitled, "Structure and Style," a collection of outstanding English prose selected as a basis for literary instruction in college courses. This recognition placed Dr. Hall in the same category with writers such as Thomas Carlyle, John Ruskin, John Galsworthy, Stuart Chase, John Erskine, H. G. Wells, John Stuart Mill, Sir Arthur Quiller-Couch, H. L. Mencken, and others whose writings appear in the same volume.

Dr. Hall's paper was concerned with the desirability of requiring applicants for political appointments to pass appropriate examinations similar to those required by the Civil Service Commission for applicant's for government jobs in the classified service.

The research work of the division remained under the direction of Dr. Hall until April 1, 1936, when he resigned from the BAI to accept a position in the Treasury Department as Head of the Zoological Laboratory of the National Institute of Health, Bethesda, MD. Dr. Hall took with him four research scientists from the Zoological Division: Drs. Eloise B. Cram and Myrna G. Jones, poultry parasitologists; Willard H. Wright, of the Anthelmintic Project; and Mr. John Boziecevich, of the Ruminant Helminth Parasite Project.

Dr. Schwartz was appointed acting chief after Dr. Hall's departure, and was promoted to division chief on May 1, 1936.

Regional Animal Health Laboratory, Auburn, AL—One of the four regional laboratories established by the BAI in 1937, after the passage of the Bankhead-Jones Act of 1935, was the Regional Animal Disease Laboratory at Auburn, AL. The region included the 13 traditional Southern States: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. The laboratory was mandated to select for investigation, "the gastro-intestinal parasites of all domestic animals and poultry with first and major emphasis on coccidiosis, (including) detailed studies of the morphology and development of the parasites, studies on the eggs and larvae in relation to the environment, in order to obtain fundamental information on which to base control methods, studies of the intermediate hosts in cases involving such hosts with a view to breaking the parasite cycle by controlling or eliminating the intermediate hosts in question, portal of entry of the parasites and the course of migration in the host, susceptibility and resistance of the host to the parasite infection." The study of two practically untouched problems in parasitology was also to be undertaken: the interrelation between the host's nutrition and its susceptibility to parasitism and the varying susceptibility to parasitism of different species of domestic animals and poultry. These phases were to be studied from the zoological, ecological, pathological, immunological, and epizoological standpoints. These purposes and objectives were to be sought by a research program including the research of the laboratory

and the research of the cooperating State stations, approved annually by the Bureau chiefs concerned and the directors of the cooperating State experiment stations. The research program was to be planned each year by a representative of each State agricultural experiment station of the region, designated by the director, the director of the regional laboratory and representatives of the BAI and the Office of Experiment Stations.

When the main laboratory building at Auburn was completed, Dale A. Porter, a parasitologist of the Zoological Division, stationed in Moultrie, GA, accepted it for the Government. He transferred to the Auburn laboratory in February 1938, the first member of its scientific staff. He became director of the regional laboratory in 1949 and held this position until he resigned in 1966 to go to India.

Three substations of the regional laboratory were established beginning in 1948, with the opening of a laboratory at Angleton, TX, for the study of cattle helminths, principally, liver flukes. The cattle used in the experiments were part of the State prison farm herd, and labor was supplied by prison inmates. On one memorable day, George Cauthen, a research veterinarian, was overpowered by the inmates working with him on the farm, who stripped him of his clothes, tied him up, and stole his watch. When Dr. Cauthen didn't show up at the end of the day, station personnel instituted a search and found him securely tied to a fence. They released him from his bonds apparently none the worse for his experience, except for exposure to an intensive mosquito attack. The Angleton substation was closed in 1951, at about the time the External Parasite Laboratory was activated at Las Cruces, NM. A second substation for cattle helminth research was opened at Griffen (Experiment), GA, in 1949. This station is still under the Regional Laboratory's direction. A third substation was established in 1955 at State College, MS, for research on sheep helminth parasites. This station was closed when the parasitologist, Robert A. Knight, was transferred to the Beltsville Parasitological Laboratory in 1966.

Moves and Name Changes

All division personnel assigned to Washington, DC, were transferred to Beltsville in 1942, except Dr. Schwartz and his secretary. They remained in Washington until the early fifties, when they also moved to the Beltsville Laboratory. Dr. Schwartz continued as chief of the Zoological Division until the Department of Agriculture was reorganized in 1953, eliminating the Bureaus. At that time various laboratories of the Zoological Division became autonomous units, the largest being the Beltsville Parasitological Laboratory of the Animal Disease and Parasite Research (ADPR) Branch (later, Division) of the Agricultural Research Service (ARS). Dr. Schwartz's title was changed to Consultant in Parasitology. Dr. Schwartz retired in 1959 and was succeeded by the late Edwin R. Goode, of the ARS National Program Planning Staff, in an acting capacity, until Aurel O. Foster, the scientist in charge of chemotherapy research, was appointed director of the Beltsville Parasitological Laboratory in 1960.

In 1960-61, the Beltsville Parasitological Laboratory moved to a 400-acre tract with buildings on the south side of the Beltsville Agricultural Research Center, east of Edmonston Road, that had been vacated in 1959 by the Animal Disease Station of the ADPR Division, when it moved to Ames, IA. Many aspects of the parasite laboratory's move to the new location were photographed in color by Robert G. Leek of the laboratory staff and a thirty-minute 16 mm sound movie narrated by Everett E. Lund and edited by John Andrews, was made to record the historic event. The film currently is stored at the Animal Parasitology Institute, Beltsville. The building currently (1986) is the headquarters of the Animal Parasitology Institute. The change in location greatly expanded the laboratory's capacity for raising and pasturing farm animals and for carrying on pasture experiments.

Dr. Foster retired in 1971 and was succeeded by Frank D. Enzie, veterinary medical officer and associate director of what had become the National Animal Parasite Laboratory. In 1972 the name of the laboratory was changed to The Animal Parasitology Institute, and the title of Director to Chairman. Dr. Enzie retired in 1979 and was succeeded by Harry Herlich, then chief of the Ruminant Helminthic Diseases Laboratory, as Institute Chairman.

On January 4, 1984, Dr. Herlich retired and Ronald Fayer, chief of the Ruminant Parasitic Diseases Laboratory, became the new Chairman. And on this date the institute itself underwent a major internal reorganization. The three host-oriented laboratories and the Parasite Classification and Distribution Unit were abolished and were replaced by three new laboratories, with titles emphasizing the role of the parasite in the Institute's research program. The new laboratories were Helminth Diseases Laboratory, with K. Darwin Murrell, former chief of the Nonruminant Parasitic Diseases Laboratory, as chief; Protozoan Diseases Laboratory with Michael D. Ruff, former chief of the Poultry Parasitic Diseases Laboratory, as chief; and Biosystematics Laboratory with J. Ralph Lichtenfels, former chief of the Parasite Classification and Distribution Unit, as chief.

PARASITES AND PARASITIC DISEASES

Ruminants

Texas Cattle Fever—Shortly after the Department of Agriculture was established in 1862, its attention was attracted to one of the earliest recognized economically important diseases of livestock in the United States, Texas cattle fever. The disease had been brought into this country in the 1600's in cattle imported from the islands of the Caribbean, and by 1862 it was causing tremendous losses to cattlemen, particularly in the Northern States. No one knew the identity of the causative agent nor how to prevent its spread from Southern cattle, in which it was endemic, to Northern cattle. The latter were highly susceptible and a large percentage of those becoming infected died. Although cattlemen had thought for years that the cattle tick somehow was associated with its transmission to healthy cattle, no one had been able to prove the relationship.

John Gamgee, of the Albert Veterinary College, London, England, happened to be in this country in 1868 at the time of a severe outbreak of Texas cattle fever and the Agriculture Department hired him to investigate the disease. Although he was unable to find the cause, he discovered that the disease occurred in areas where the "so-called malaria" injuriously affected human health. He said that the tick theory of transmission of Texas cattle fever was *absurd*.

Ten years later, Daniel E. Salmon was asked by the Commissioner of Agriculture, William G. LeDuc, to investigate animal diseases in the Southern States with special reference to Texas fever. He also failed to discover the cause, but *did* find that susceptible cattle had to graze on land with infected cattle or on pastures that had been grazed by them in order to become infected. At this time, Dr. Salmon said, ". . . the tick theory scarcely explained a single one of the very peculiar phenomena of the disease."

Pioneers in work on identification of the cattle tick as the vector of Texas cattle fever.

THEOBALD SMITH

COOPER CURTICE

FRED KILBOURNE

Richard C. Stiles, in 1869, reported the earliest observation which laid any stress upon the changed condition of the blood corpuscles in Texas cattle fever, but he didn't relate the changes to any causative agent. It was not until 1888 that Theobald Smith of BAI noted the destruction of the red blood corpuscles in the blood of cattle with Texas fever, and in 1880 Dr. Smith discovered the causative agent of the disease, *Piroplasma bigemina*.

This organism, later named *Babesia bigemina*, was found to belong to a group of blood parasites causing piroplasmosis (Babesiosis), a febrile and often fatal disease of cattle and horses and related animals.

In the same year, Fred L. Kilborne showed experimentally that ticks had something to do with the disease, and Cooper Curtice worked out the essential facts of the life history of the cattle tick, which had not been adequately investigated. This tick had never been named, so Dr. Curtice named it *Boophilus* (cattle lover). He determined for the first time that it spent its entire developmental cycle on only one host, beginning with the seed tick that crawled from the grass onto cattle, and that it did not drop off the host after each molt as other ticks did. This in itself was a novel discovery, so far as tick life histories were concerned. Dr. Curtice also noted the time required for the tick to develop from the

egg through the stages of its life cycle, to the engorgement of the female tick that took place before it dropped off the animal and fell to the ground. In addition, he learned from these experiments that it was possible to rear on cattle the seed ticks that hatched from the eggs deposited by the engorged females on the ground.

According to Dr. Curtice: "Neither Dr. Salmon, Dr. Smith, nor Dr. Kilborne had any idea in 1889 of trying ticks out as a means of inoculating cattle with Texas fever directly. . . . This idea held with each as late as my presentation of the biology of the cattle tick on February 3, 1890, as each of them repudiated my idea that ticks of themselves could do harm to cattle and led me to state that it was a simple matter to ascertain by putting young ticks on the cattle. Later, I specifically asked Dr. Salmon for four head to try the experiment during the coming summer."

In his paper entitled, "The Biology of the Cattle Tick," Dr. Curtice stated: "Aside from the purely biological interest excited by the above is the practical one of the relation of the tick to Texas cattle fever. Having learned to breed the ticks in quantity I conceived the idea of taking Northern calves and placing young ticks upon them to determine the extent and kind of injury that the ticks should cause their hosts."

These experiments were conducted in the summer of 1890 by Drs. Smith and Kilborne while Dr. Curtice was on another assignment. The results showed that northern cattle purposely infected with cattle ticks afterwards presented all the symptoms of southern cattle fever, and harbored in their blood the protozoan parasites which Dr. Smith believed to be the cause of the fever. *Most importantly, these experiments, for the first time in history, showed that a disease agent could be transmitted from an infected animal to an uninfected one by means of an arthropod host*, and provided the clue for the development of control measures for malaria, yellow fever, typhus fever, African sleeping sickness, Rocky Mountain spotted fever, nagana, and others. Because of certain errors in the allotment of credit for the initiation of the experiments, Dr. Curtice did not receive proper recognition for his contribution to them. Dr. Smith's report of the Texas fever experiments is an American classic and he freely acknowledged that it contained errors in assigning credit for the accomplishment.

As both adults and young ticks produced the fever, the necessity for preventing their spread onto northern pastures, as one means of preventing the spread of Texas cattle fever, was made clear. Dr. Curtice firmly believed that the destruction of cattle ticks would free the country of Texas fever, but he got little if any backing from the Bureau hierarchy.

At this point, his rebellious nature paid off. After leaving the Bureau in 1891, he conducted a campaign to obtain support for testing his belief that cattle tick eradication would result in the demise of Texas cattle fever. He did this from his home in Moravia, NY, "at great personal sacrifice," according to an unpublished account of his life by Lee Butts Curtice, a grandson.

Dr. Curtice returned to the Bureau in 1894 and was assigned to work in Virginia in 1895. One of his duties was to retrace the quarantine line separating tick infested areas from tick-free areas. Before leaving Washington, he asked Dr. Salmon if he should base his findings on the presence of ticks or on the report of disease. He replied, "on ticks." Dr. Curtice said that this was Dr. Salmon's first acknowledgement to him that tick country was identical with Texas fever country and that the absence of ticks indicated disease-free country.

Dr. Curtice remained with the Bureau only 2 years, as he was summarily fired without prior notice on November 28, 1896, after he published an unauthorized article in *Southern Planter* stressing the need for Federal and State participation in the eradication of the cattle tick. Dr. Curtice stated, "There is no sanitary work connected with cattle that will pay the State and Federal Government so large returns on the money expended as an extended campaign for the extermination of ticks from the infested areas." It was this article that gained for Dr. Curtice the titles "Father of Tick Eradication," and "Dr. Ticks." In 1899, as State veterinarian of North Carolina, Dr. Curtice was able to prove that tick eradication would also eradicate Texas cattle fever. (Dr. Curtice rejoined USDA in 1914, remaining until 1930.)

In 1905, James Wilson, Secretary of Agriculture, announced his decision to take up tick eradication work in cooperation with the States, and in 1906, the first appropriation for the program became available. Work was begun and Dr. Curtice returned to the BAI and was put in charge of tick eradication in Virginia and North Carolina.

In 1907, investigations were begun in the Zoological Division, in cooperation with the Biochemic Division of BAI, to determine the effective strength and conditions of use of arsenic solutions for destruction of cattle ticks. In 1909, pasture rotation was tried as a method for controlling the cattle tick, and in 1910, the first arsenical dip (made from white arsenic, soda, and pine tar) was permitted for use in official dipping after field tests observed by the Zoological

Division had shown it to be effective.

Howard Crawley, the protozoologist of the Zoological Division, in 1913, found small, cigar-shaped protozoan parasites in smears of infectious cattle fever ticks and crushed eggs which they had deposited—parasites, similar in appearance to those seen in South Africa and considered to be a stage in the development of *Piroplasma bigemina*, the causative agent of Texas cattle fever. These observations were published in 1916 and the Tick Eradication Division of the BAI was established in 1917.

There can be no question but that much of the agricultural development in the South that has taken place during the last few decades is the direct result of tick eradication. Without that, the beef and dairy industries in the South would have been no farther advanced than they were in the beginning of the present century. Actually, tick eradication created a revolution in the agricultural economy of the South by making it possible to develop that area into an important livestock region.

In 1913 the American Veterinary Medical Association presented Dr. Curtice with a medal in recognition of his pioneer work in veterinary science and particularly in recognition of his contribution to our knowledge of tick fever and of the role of the tick *Boophilus annulatus* as the vector of the causative organism, *Babesia bigemia*. This recognition was the first demonstration of appreciation at the national level of Dr. Curtice's key role in the successful effort that brought about the eradication of this scourge of the cattle industry.

In his sketch of Dr. Curtice's life, Gerard Dikmans of the division noted: "Dr. Curtice's chief contribution to parasitology was undoubtedly his discovery of the life history of the cattle fever tick. This discovery, while interesting, would not have been of major importance except for the fact that this discovery enabled other workers in the Bureau of Animal Industry to demonstrate experimentally and beyond the peradventure of doubt, that the cattle tick, *Boophilus (Margaropus) annulatus*, was the definitive host and transmitter of tick fever of piroplasmosis."

By 1954, application of the standard arsenical dip treatment at 14-day intervals had resulted in the eradication of both species of cattle ticks, *Boophilus (Margaropus) annulatus*, and *B. microplus*, in the 15 States originally infected, with the exception of a narrow zone along the Texas-Mexico border, where reinfestation occurred from time to time because the adjacent area in Mexico was heavily infested.

Venereal Trichomoniasis—Bovine trichomoniasis was found to occur in 23 States in 1938. The disease was diagnosed in the dairy herd on the Government-owned farm at Beltsville, and in 1939 studies were begun on the development of immunity to *Trichomoniasis foetus*, the causative organism, under experimental conditions.

In 1947, David E. Bartlett, of the Zoological Division, showed that venereal trichomoniasis could be transmitted by means of artificial insemination and in 1948 he demonstrated that a combination of trypaflavine and sulfur was an effective local treatment for bulls infected with *T. foetus*. Louis S. Diamond, protozoologist in the Beltsville Parasitological Laboratory, in 1957 devised a culture medium for growing *T. foetus*, *in vitro*, permitting a more accurate diagnosis of bovine venereal trichomoniasis. Donald K. McLoughlin, also a protozoologist in the Beltsville Parasitological Laboratory, found in 1963 that Dimetridazole, a substituted imidazole compound, was a safe and effective therapeutic agent against *T. foetus* and that it could be administered either orally or intravenously.

Bovine Coccidiosis—John F. Christensen and Dale A. Porter, working at the new Regional Animal Disease Research Laboratory at Auburn, AL, described a new species of coccidia in 1939, which they named *Eimeria auburnensis. E. auburnensis* was mildly pathogenic, but when present in a calf at the same time as a very pathogenic species, such as *E. zurni*, it became more severe in its effects, causing severe diarrhea and emaciation in the affected calves. A total of nine species of coccidia were found in cattle during the investigations of bovine coccidiosis at this laboratory.

In 1941, Aurel O. Foster, head of chemotherapy investigations at the Zoological Division in Beltsville, and collaborators discovered that sulfa drugs were useful for the control of coccidiosis in domestic animals and poultry.

Datus M. Hammond and Leonard R. Davis found in 1944 that the severity of coccidiosis in cattle resulting from experimental infections with *Eimerla bovis* varied with the number of oocysts given by mouth. Free sporozoites and empty cysts were found in the lower portion of the small intestine, and cecum and colon, respectively, 18 hours after experimental ingestion of the oocysts.

Sarcosporidiosis—In 1893, Charles W. Stiles described and named three species of sarcosporidia, all of which were from birds. In 1909, Howard Crawley, the division's first protozoologist, published descriptions of new species of sarcocystis, a muscle parasite, in addition to life-history studies on *S. muris* and studies on the systematic position of sarcosporidia. In 1912 his studies on the protozoan parasites of domestic animals were published. Mr. Crawley in 1914 confirmed the findings of Negre, an Italian parasitologist, that the feces of mice from the 15th to the 60th day after being fed *Sarcocystis*-infected meat contained a resistant stage of the organism that will resist drying and produce *Sarcocystis* infections in other mice if ingested. These results suggest that strictly herbivorous aminals in which sarcosporidia are very common may become infected by ingesting resistant forms in the feces of omnivorous or carnivorous animals.

CHARLES WARDELL STILES

Dr. Charles Wardell Stiles, Assistant-in-Charge, Zoological Laboratory, Division of Pathology, BAI, (1891-1903).

In 1972, Ronald Fayer, then a protozoologist in the Animal Parasitology Institute (API), cultivated *in vitro* in cell culture the muscle parasite, the sarcosporidian *Sarcocystis fusiformis*, which occurs in birds, man, livestock, and other animals, and proved for the first time that it was a coccidium. In 1974, he elucidated the life cycle and pathogenesis of this parasite in domesticated animals. In 1975, he found that coyotes had a role in the transmission of bovine sarcocystosis. In 1976, Dr. Fayer demonstrated that *Sarcocystis* spp. could cause abortion in sheep and cattle, and two years later he developed a test to identify the parasites in the tissues of pregnant cows. He also found *Sarcocystis* in fresh beef, hamburger, round steak, and chuck roasts, and in rare roast beef purchased from supermarkets in the Washington, DC, area. Because one of the four known species of *Sarcocystis* in beef is infectious for man, this finding suggested the public health potential of this group of organisms. Dr. Fayer's work on *Sarcocystis* resulted in 1978 in his receiving the Agriculture Department's Superior Service Award and the Henry B. Ward Medal from the American Society of Parasitologists for the overall excellence of his research and teaching ability in the field. In 1979, Dr. Fayer transmitted from cow to cow, sheep to sheep, and pig to pig, virtually unknown blood-borne stages of *Sarcocystis* via transfusion of small amounts of blood, indicating a possible role that blood sucking insects may play in the transmission of this parasitic disease. In 1980, Dr. Fayer found that dairy cows experimentally infected with *Sarcocystis* produced much less milk and lower quality milk than did uninfected cows. The high prevalence of *Sarcocystis* infection in U.S. cattle, therefore, may have a profound economic significance which has heretofore been unrecognized.

In 1982, Louis C. Gasbarre developed two techniques for detecting the immune responses of cattle and sheep infected with *Sarcocystis*: the ELISA test (for Enzymlinked Immunosorbent Assay); and the lymphocyte blastogenesis test, which measures the activity of certain white blood cells in response to the infection. A third technique for detecting

the cellular immune response to *Sarcocystis* infection requires the injection of minute quantities of parasite antigen into the skin. Reactive cells migrate to the site of the injection, producing a swelling which can be measured to determine the strength of the response. These techniques are being used to study the nature of the host immune response, for development of effective vaccines and as diagnostic tests for sarcocystosis in farm animals.

Piroplasmosis—Kenneth Kuttler, veterinary protozoologist at API, demonstrated in 1980 that an experimental, nonviable and soluble *Babesia bovis* antigen, which was derived from tissue culture, was immunogenic against *B. bovis* challenge. He also prepared complement-fixation serological antigens using *B. bovis* and *B. bigemina* and used them successfully to identify both acutely and chronically infected cattle. Vaccinal titers resulting from a *B. bovis* vaccine were readily measured by the indirect fluorescent antibody test, but were not apparent by the complement-fixation test, although after challenge and infection positive C.F. titers occurred. *B. bovis* organisms were grown successfully on erythrocyte cell cultures at the University of Missouri as part of a cooperative project with that institution. Attempts to transmit *B. bigemina*, the causative agent, using the winter tick, *Dermacentor albipictus*, were unsuccessful.

Worm Parasites—Parasitic bronchitis of calves was one of the first helminthic diseases investigated by the BAI when it was established in 1884, and in 1887 the results of investigations of liver and lung flukes of cattle were published.

Shortly after C. W. Stiles entered the BAI, he reported the occurrence of the stomach worm *Strongylus ostertagi* (*Ostertagis ostertagi*, Stiles 1892) in U.S. cattle for the first time. Also in 1892, he published an account of *Gongylonema scutatum* (Muller, 1869) a common roundworm parasite in the mucosa of the esophagus of sheep and cattle, enlarging upon earlier more imperfect descriptions. B. H. Ransom and M. C. Hall worked out the life history of this parasite in 1915. They found that the eggs passed in the feces of the host were ingested by dung beetles, that the larvae developed to the infective stage in these insects and completed their development to maturity when the infected insects were ingested by sheep or cattle on pasture. The discovery that cockroaches could be readily infected with this parasite in the laboratory proved very useful in studying the larval stages of the worm; the roaches could serve as experimental hosts.

Drs. Stiles and Hassall published a revision of the adult cestodes (tapeworm) of cattle, sheep, and allied animals in 1893, a revision which included descriptions of two new species, *Moniezia planissima* (Stiles and Hassall, 1893), and *M. trigonophora* (Stiles and Hassall, 1893). In 1894, Dr. Stiles published a detailed description of the large American liver fluke *Fascioloides magna* together with a comparison with other flukes and a summary of the available information of fascioliasis (liver fluke disease). In the same year, the results of investigations of infectious and parasitic diseases of domesticated animals were reported in BAI Bulletin No. 3 and the adult cestodes mentioned above were described in BAI Bulletin No. 4.

ALBERT HASSALL

Dr. Hassall, Assistant, Division of Pathology, BAI (1891-1902); Veterinary Inspector, Meat Inspection Division, BAI (1902-1904); Assistant in Zoology, Zoological Division, BAI (1904-1910); Assistant Zoologist, Zoological Division, BAI (1910-1928); Senior Zoologist and Assistant Chief, Zoological Division, BAI (1928-1932); Collaborator, Zoological Division, BAI (1932-1942).

In 1898, Stiles and Hassall published an important paper on the flukes and tapeworms of cattle, sheep, and swine, with special reference to meat inspection and an inventory of genera and sub-genera of the trematode family, Fasciolidae. In 1900 they completed their studies on the life history and pathogenicity of the rumen fluke, *Amphistoma cervi*, and in 1901 they reported on the verminous diseases of cattle, sheep, and goats in Texas.

In 1914, Dr. Ransom reported results of investigations begun in 1911 showing that beef infected with *Cysticercus bovis*, the larval form of *Taenia saginata*, the beef tapeworm of man, was safe for human consumption if kept at a temperature not higher than 15°F for 6 days.

Dr. Hall reported in 1915, for the first time the presence of *Syngamus laryngeus*, a tapeworm, in cattle and the carabao in the Phillipines and in 1916, Dr. Ransom published a report on the animal parasites of cattle. Henry G. May, junior zoologist, in 1920 described four new species of nematodes belonging to the genus *Nematodirus* from domestic ruminants: *N. abnormalis*, *N. dromedarii*, *N. furcatus*, and *N. helvetianus*. Also in 1920, the first finding of a tapeworm in cattle (*Syngamus laryngeus*), in the Western Hemisphere was recorded in the Zoological Division on the examination of a parasite sent to it for identification by Dr. Bague. That same year, Dr. Ransom reported species of *Onchocerca* (muscle parasites) from cattle in the United States for the first time. He also noted that the intestinal threadworm, *Cooperia punctata*, caused pronounced lesions of the digestive tract of calves, with resultant injury and death. Dr. Hall in 1921 first reported finding the swine kidney worm, *Stephanurus dentatus*, in cattle in the United States.

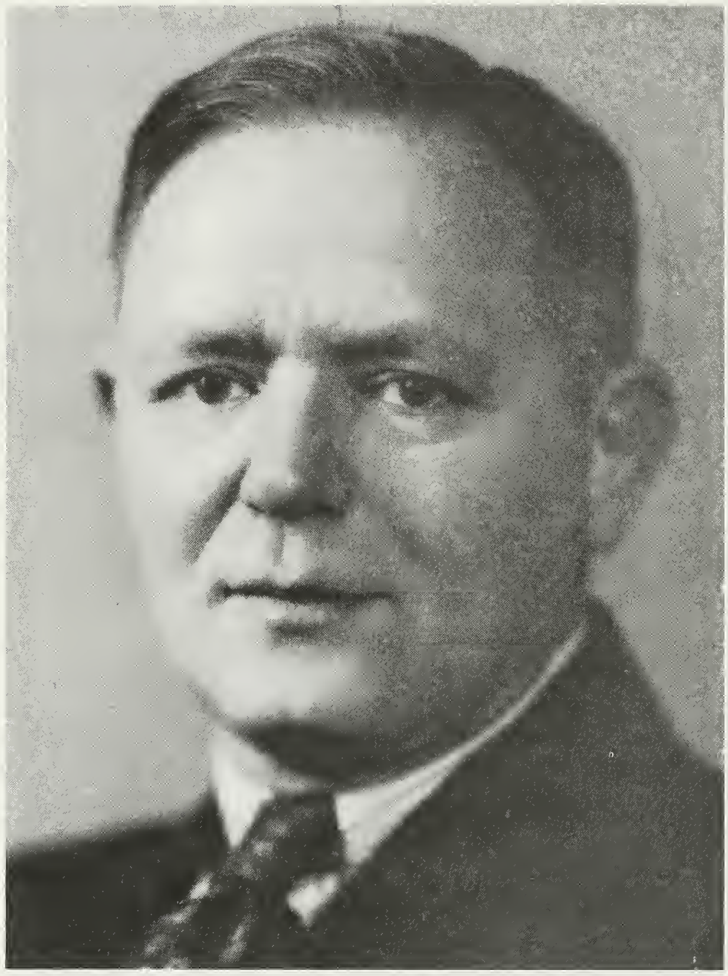
BRAYTON HOWARD RANSOM

Dr. Ransom had great practical influence in systematizing our knowledge of nematodes parasitic in the alimentary tract of cattle, sheep and other ruminants, set much needed standards in accuracy of detail and care in classification, described many new species of worms parasitic in both domesticated and wild animals, reported for the first time from the United States many parasites of domesticated animals already known in Europe and elsewhere, and, last but not least, devised the McLean County (Illinois) System of Swine Sanitation, as a means to control infection of young pigs with internal parasites.

Research on the helminth parasites of cattle was again evidenced by the publication in 1922 of Dr. Hall's paper describing the lungworms of domestic animals, and the eggs and larvae of the internal parasites of cattle, sheep, and goats. In another paper he discussed the relationship of parasitism to eosinophilia.

Dr. Ransom published papers on the parasites of cattle and on the use of the guinea pig and the pure culture for the study of animal parasites in 1923.

Dr. Schwartz reported the finding of *Ascaris* sp., a large intestinal roundworm in American cattle in 1925. In 1928, Emmet W. Price found for the first time in cattle a nematode (named *Cooperia bisonis*) previously reported by Dr. Cram from the American bison. Also in 1928, Dr. Hall noted that the survey of parasites in the United States, which had just been completed, disclosed a more general distribution of these pests than had been thought to be the case. He prepared "Calendar of Parasites" for general distribution to improve availability and timeliness of known control measures by supplying seasonal information associated with their proper application.



BENJAMIN SCHWARTZ

Dr. Schwartz was a very early worker on the effects of x-rays on parasites, on toxins, tumors, immunity, pathogenicity, zoonosis, and other parasitological phenomena, who, through his prolific writings, extensive travels, contacts, untiring service in many capacities, and concern about problems affecting the welfare of man and his domestic animals, went far to establish parasitology as something more than of casual or even zoological interest and importance. He did much for the Zoological Division that he served well for so long, and also much for parasitological science not only in the United States, but throughout the world.

In 1930, a *Strongyloides* was found for the first time in American cattle and its life history studies. In no case did the usual free-living males and females develop from the eggs of the parasite; in all cases there was direct development to infective larvae. The disposal of cow manure by storing it in specially constructed boxes resulted in the destruction of parasite eggs and larvae from heat spontaneously generated in the cow manure.

A survey of cattle parasites at the Regional Animal Disease Research Laboratory at Auburn, AL, revealed in 1939 that all the common parasites reported from cattle elsewhere in the United States were present in cattle in that area. The gastrointestinal roundworms *Haemonchus contortus*, *Cooperia punctata*, *Ostertagia ostertagi*, *Trichoestrongylus colubriformis*, and the lungworm *Dictyocaulus viviparus*, all known pathogens, were among them.

Rex W. Allen in 1947 determined the thermal death point of the larval stages of the "beef tapeworm" *Taenia saginata* to be 56-57°C. (132.8-134.6°F). This, for the first time, provided accurate information on the temperature to which meat containing this parasite must be heated in order to make it safe for human consumption.

John T. Lucker and Dr. G. Dikmans in 1950 described the development of bovine cysticercosis, and thus provided invaluable information for determining the age and hence the probable source of infection in beef carcasses. This information was necessary in implementing control and eradication programs with a view to eliminating the parasite and to establishing appropriate procedures in connection with Federal meat inspection regulations.

Frank Douvres in 1956 elucidated the life cycle of the medium stomach worm, *Ostertagia ostertagi*, the most important nematode pathogen of cattle in the United States. In 1957, Dr. Douvres developed differential diagnostic keys for the identification of all immature stages of eight of the most common gastrointestinal worm parasites of cattle, and showed that *Trichostrongylus* and *Ostertagi*, two genera of nematode parasites of cattle, were transmissible to swine. Frank G. Tromba and Dr. Douvres proved in 1958 that the red stomach worm of swine, *Hyostrongylus rubidus*, was easily transmitted to calves, in which it produced a disease similar to that in the porcine host.

In 1962, the *in vitro* technique for cultivating *Oesophagostomum radiatum*, the nodular worm of cattle, was used for

the first time to demonstrate immune and nutritional response between host and the parasite. The immune response was indicated by the formation of precipitates at the body openings of living larvae advancing through the parasitic third stage and third moult (tissue phases) and by the coating of their body surface with these precipitates. This reaction was attributed to the presence of extracts of tissues obtained from a yearling singly infected with *O. radiatum* and from one resistant to this parasite. No reactions occurred in the presence of extracts from noninfected bovines. It was deduced that (1) antibodies are present and can be extracted from intestinal tissues of bovines infected with, or resistant to, a nematode which has no migratory phase and only minimal tissue invasion, and (2) antigens that react specifically with these antibodies were produced by larval stages grown *in vitro*.

The preference of third-stage larvae for invasion of the small intestine *in vivo* was reflected by enhanced development *in vitro* through the third stage and third molt in media containing extracts of small intestinal tissues or of the mucus and ingesta from this organ.

By 1970, Dr. Douvres found that it was possible to produce large numbers of *O. radiatum* using his medium KW2, and a roller culture system with and without cells; but the worms developed only to the fourth stage. Ten years later, Dr. Douvres reported that he had been able to cultivate the ruminant gastrointestinal hairworm *Trichostrongylus colubriformis, in vitro* to young adult stages after the infective larvae were stimulated to exsheathe with a 70-minute exsheathing process. The larvae completing exsheathment were cultured in four different two-step roller-culture systems for 16 to 27 days. This system produced maximal yields of less than 1 percent young adults in populations of about 100,000 *T. colubriformis* by days 16 to 28.

In 1983, Dr. Douvres found that in 28 to 52 days the larvae of *Oesophagostomum radiatum* developed to the fourth moult from exsheathed infective larvae in complex Medium API-1, with or without the addition of glutathione (reduced) or a bovine heme. Further development depended on the presence of bovine heme, which allowed the larvae to become young adult males and females within 25 to 35 days. The most advanced stages attained were young adult males and females in which mature reproductive systems showed the beginning of spermatogenesis and oogenesis. This system produced maximal yields of up to 25 percent young adults in populations of about 80,000 *O. radiatum*, by days 28 to 42.

In 1965, Halsey Vegors and John Lucker demonstrated that partial immunization of calves against lungworm, *Dictyocaulus viviparus*, could be produced by oral vaccination with the less pathogenic related species, *D. filaria* of sheep. The next year these investigators immunized cattle against beef measles by feeding them xray attenuated eggs of the beef tapeworm, *Taenia saginata*.

Honorico Ciordia, at Griffin, GA, in 1968, elucidated the complex interrelationships between the environment and the epidemiology of helminthic diseases in cattle, and in 1970, Harry Herlich demonstrated that the sheep nodular worm, *Oesophagostomum columbianum*, produced intestinal lesions in calves and thus contraindicated management practices recommending mixed or alternate grazing of pastures by cattle and sheep to control gastrointestinal parasites.

Maybelle (Mrs. B.G.) Chitwood, in 1971, identified a nematode found in the face fly, *Musca autumnalis*, as the larva of the eyeworm, *Thelazia gulosa*. This was the first report of a natural vector for the eyeworm of cattle in eastern North America.

In 1982, Dr. Lichtenfels noted that lungworms (*Dictyocaulus viviparus*) and two species of trematodes, *Fasciola hepatica* and *Fascioloides magna* were economically important parasites of ruminants in the Gulf Coast States, on the Pacific Coast and in the Great Lakes region.

Anaplasmosis—Anaplasmosis was diagnosed in cattle in Florida in 1928 and a study of the disease was inaugurated at Jeanerette, LA. *Anaplasma marginale*, the causative organism, was once considered to be a protozoan, but is now known to be a *Rickettsia*, a member of the type genus of the family Rickettsiaceae, Order Rickettsiales, comprising pleomorphic, rod-shaped, nonfilterable microorganisms that live intracellularly in biting arthropods. When transmitted to man and other vertebrates by the bite of an infected arthropod host, they cause a number of serious diseases, including Rocky Mountain spotted fever and typhus in man and anaplasmosis in cattle and sheep. The investigations in Louisiana demonstrated in 1929 that *A. marginale* could remain in the blood stream of a cow 20 months after experimental inoculation and after the cow made a complete recovery following several weeks' illness. They also developed the fact that the disease in Louisiana was identical with anaplasmosis in other parts of the world.

Anaplasmosis was transmitted experimentally by seed ticks from females of the Texas-fever tick, *Margaropus* (*Boophilus*) *annulatus*, in one out of four attempts—the first experimental transmission in this country. Other experiments showed that anaplasmosis was inoculable from animal to animal by blood transfer; that an animal recovered from the mosis was inoculable from animal to animal by blood transfer; and that an animal recovered from the disease was relatively immune to a second inoculation, although the duration of immunity was not ascertained. An animal recovered from the disease remained a carrier for at least 3 years; blood from an animal with anaplasmosis could be injected into a sheep without producing any visible effects, but when blood from the sheep was withdrawn 30 days after the injection and injected into a susceptible sheep, it produced anaplasmosis; and the disease could not be transmitted to rabbits or guinea pigs by blood inoculation.

Charles W. Rees reported in 1930 that the dog tick *Rhipicephalus sanguineus* could transmit anaplasmosis and that both anaplasmosis and piroplasmosis could be carried from infected to susceptible animals by pricking the ear of an infected animal and pricking the ear of a susceptible animal with the same instrument. In 1932, he reported the experimental transmission of the disease by *Dermacentor andersoni* and *D. variabilis*.

In January 1933 the anaplasmosis project was moved from Jeanerette, LA, to the Beltsville Parasite Laboratory along with the project leader, Dr. Rees, and two assistants.

Dr. Rees in 1937 demonstrated the feasibility of preserving the etiologic agent of bovine anaplasmosis, *Anaplasma marginale*, by storage at dry-ice temperature (-78.6°C.), and Drs. Rees and Maurice W. Hale reported on their morphological and chemical studies of the blood of cattle in health and during anaplasmosis.

Dr. Rees determined in 1938 that it was possible to detect anaplasmosis in a herd by injecting composite samples of blood into a known carrier from which the spleen had been removed. Such splenectomized animals could be used over and over again for the purpose indicated. John C. Lotze found in 1941 that the horse fly, *Tabanus sulcifrons*, could transmit anaplasmosis directly from infected to susceptible cattle, and in 1942 he showed that *A. marginale* developed in red blood cells by progressive multiplication, with the marginal body containing up to eight smaller units. This observation was confirmed in 1967 by D. W. Gates, Thomas O. Roby, and colleagues who, using the electron microscope, also saw that *.A. marginale* was composed of several parts. The most prominent part, the one seen through the light microscope, was an electron-dense mass composed of four or more parts, each surrounded by a double-walled membrane. This mass was believed to be nuclear (i.e. nucleoplasm). Not ordinarily seen by conventional microscopy was a narrow ring of cytoplasm-like material surrounding the "nucleoplasm" that may be comparable to the cytoplasm of other protozoan and mammalian cells. Studies of the ultrastructure of the parasite are yielding important clues as to its biological nature.

John C. Lotze showed in 1944, that asymptomatic carriers of anaplasmosis were sources of infection and that the parasites in their blood could easily be transmitted to healthy cattle by biting flies.

T. O. Roby, in cooperation with researchers at State experiment stations in Louisiana, Maryland, and Oklahoma, in 1952 developed the complement-fixation test as a practical and standard laboratory method for the diagnosis of both acute and carrier cases of anaplasmosis. And in 1963, D. W. Anthony established the fact that the male Rocky Mountain wood tick is capable of harboring the causative agent of bovine anaplasmosis through the winter months, thus providing a mechanism for the re-infection of cattle in the spring.

Gene Amerault and Dr. Roby devised a rapid card agglutination test in 1968 for the serological diagnosis of bovine anaplasmosis on the farm as well as in the laboratory, which was recognized as an official test by Federal and State regulatory officials in 1973.

Dr. Roby discovered in 1971, in cooperation with several Western States, that *A. marginale* was prevalent as a latent infection in black-tailed deer inhabiting the coastal range of California; that the Pacific coast tick was an efficient vector of anaplasmosis; and that bison, antelope, and mule deer in the Rocky Mountain States were relatively free from bovine anaplasmosis. These facts are important elements in understanding the epidemiology of this disease. In 1972, Mr. Amerault adapted the hemoglobin-free anaplasmosis cart test antigen for the microtiter complement-fixation test. This antigen afforded considerable economy of reagents and resulted in significantly improved accuracy.

In 1973, Dr. Roby determined that imidocarb, an experimental drug, could eliminate *Anaplasma marginale* infection in adult carrier cattle, and the following year determined that adult cattle were resistant to re-infection with *A. marginale*

after the carrier state had been eliminated by treatment with imidocarb. Dr. Roby was able to report in 1978 that 12 carriers of *A. marginale* were cleared of the parasite by injection with a new formulation of oxytetracycline without discomfort to the animals. There was no visible tissue irritation following injection of the drug.

Kenneth L. Kuttler reported in 1979 that *Anaglasma ovis*, a sheep anaplasma which is serologically related to *A. marginale*, had been successfully propagated in and recovered from a splenectomized calf, suggesting the possibility that *A. ovis* might have a potential as an immunizing agent, since it is not pathogenic to cattle. Also in 1979, Mr. Amerault developed a fast, accurate test to detect anaplasmosis in cattle.

Dr. Kuttler recovered *A. ovis* in 1980 from a calf 180 days after exposure. The identity of the recovered anaplasma was proved by cross-infectivity trials in susceptible splenectomized sheep. This was the first time an antigenetically distinct anaplasma had been identified from cattle in the United States. The possibility must now be recognized that there may be more than one antigenic type of anaplasma in cattle.

The anaplasmosis project was moved in 1981 to Moscow, ID, which is in the area where the disease actually occurs, to facilitate the implementation of a new research program in which greater emphasis is placed on a field study of the epidemiology of the disease.

Liver Flukes of Sheep and Cattle—In 1929, investigations were begun in California on the control of the common liver fluke of sheep and cattle, in cooperation with the State and other agencies. Dr. Jay, associate veterinarian, Zoological Division, was assigned to this work. He found that if flocks were running on open range, treatment with 1 cc of carbon tetrachloride in capsules, preferably given in October or November, gave good results in controlling the liver fluke. But if the sheep were in a feedlot or pasture, they had to be kept on the feed to which they were accustomed in order to avoid possible death losses from the treatment. Dr. Jay also found that the snail intermediate hosts could best be destroyed by draining marshy areas where the snails breed. Where drainage was not feasible or was too expensive, and in streams, ponds, water troughs, etc., the snails could be destroyed by the application of proper amounts of copper sulphate. On heavily infected pastures, it was found necessary to treat every 2 weeks during the season when flukes were prevalent. As this treatment kills the snails, but not the cysts of the young flukes, this application should be made early in the season before the water and grasses are infested. Copper sulphate in weak dilutions is not injurious to grasses or flowering plants, or to livestock that drink the water. Judiciously used, it will not kill fish. Filling in low areas or fencing off wet areas not suitable for copper sulphate treatment was also helpful.

In 1929, investigations in collaboration with the Meat Inspection Division of the BAI, demonstrated that fluke eggs in fluke-infected livers of animals being processed for human consumption were killed by exposure to temperatures of about 116°F for 15 minutes, to 121°F for 5 minutes, to 38°F for 6 days, and 0°F for 3 hours. Fluke eggs exposed to temperatures of 5°F to 10°F for 24 hours were killed by freezing.

In 1930, field work on the control of liver flukes in sheep and areas of work were extended. An extensive study of the snails serving as intermediate hosts of the sheep and cattle liver fluke *Fasciola hepatica* indicated that different species were hosts in different parts of the country. In the same year, deaths of sheep from carbon tetrachloride treatment were found to be associated with metabolic changes occurring when the sheep were moved from pasture to cultivated crops or put on feed at the same time they were treated.

Dr. Hall reported in 1932 that the snail *Lymnae* (*Galba*) *modicella* had been found to serve as an intermediate host of the common liver fluke, *Fasciola hepatica*, and the rumen fluke, *Cotylophoron* sp. He also determined the period of development of the fluke larvae in the snail and their effect on the snail. In 1933, Wendell B. Krull, reported new snail and rabbit hosts for the common liver fluke of ruminants, *Fasciola hepatica*.

In 1938, L. E. Swanson reported that drainage of wet areas and medicinal treatment were continued in the Rocky Mountain areas and on the Pacific Coast as control measures for the sheep liver fluke, *Fasciola hepatica*. In Montana this was done in cooperation with the State Livestock Sanitary Board. Liver fluke eggs were shown to require an abundance of oxygen to develop to the infective stage. Under field conditions, when mixed with mud and feces in water, their development could be spread over many months. Post-mortem examinations of Florida deer disclosed that *Fascioloides magna*, the large American fluke, was the only species of liver fluke in these animals. All but one bovine examined from the same area inhabited by the deer harbored *Fasciola hepatica*; that one was infected with *F. magna*.

In 1939, research on the common liver fluke, *Fasciola hepatica*, and its snail intermediate hosts was initiated in the

vicinity of Logan, UT. Four potential intermediate snail hosts were found and two others, *Lymnaea stagnalis wasatchensis* and *Fossaria modicella*, have been shown to be intermediate hosts of the liver fluke under laboratory conditions.

The Fringed Tapeworm of Sheep—The first parasitological investigation undertaken by Dr. Cooper Curtice after his appointment to the Bureau in 1886 was a study of sheep tapeworms in Colorado. Dr. Curtice's investigation of these parasites—which he identified as the fringed tapeworm (*Thysanosoma actinioides*), a species first described by Karl Diesing from sheep in Brazil, South America, in 1835—was carried on in Colorado in the late summer and autumn of 1886 and spring of 1887, and also in Washington, DC, using specimens and infected animals being shipped from Colorado for the purpose. In 1889, Dr. Curtice was the first to describe the disease caused by the fringed tapeworm. He concluded that this parasite, which was one of the most common internal parasites of range sheep in the Western United States, had a considerable influence upon the health of sheep and was very detrimental, especially to lambs and yearlings. Although sheep did not die from tapeworm disease alone, the parasite appeared to render them more susceptible to other infections and less able to withstand the inclement weather of the winter. Dr. Curtice found that the parasite persisted in the adult stage in older sheep throughout the year. He discovered very small forms in lambs as early as the beginning of the third month of life and determined that it took at least 6 months for the worms to attain their full growth. He also found that the young tapeworms were present in sheep at any age and at any time of year, except possibly the winter months. Attempts to infect lambs by feeding mature segments of the tapeworms and by keeping the lambs in pens with infected sheep gave negative results. In 1970, Rex W. Allen, a parasitologist stationed at Las Cruces, NM, obtained development of the onchospheres (eggs) of *Tractinioides* inppsocide, insects of the Order Corrodentia (also called bark lice) but was not successful in transmitting the tapeworm to sheep by feeding infected psocids to them. The life history of this tapeworm has yet to be completed experimentally. This parasite has never become established in the eastern part of the country.

The Gid Bladder Worm—The first well-authenticated case of gid (staggers) in sheep in the United States was reported by Dr. Ransom in 1905 on the basis of some specimens of *Coenurus cerebralis*, the larval form of a tapeworm of dogs, coyotes, and related carnivores, found in the brains of sheep that had died in Bozeman, MT. One outbreak, brought to the attention of the BAI in 1910, was largely responsible for the inauguration in 1910 of a Federal quarantine on imported sheep dogs. Under this quarantine provision all imported sheep dogs were subjected to fecal examination for tapeworm eggs. Also in 1910, Dr. Hall published two papers on the gid tapeworm of sheep, placing the gid parasite in the genus *Multiceps* and including a comprehensive historical review of the gid tapeworm and allied parasites.

Cysticerci, the larvae of tapeworms in the muscles of sheep, and *Fascioloides magna* the giant liver fluke of cattle and wild ruminants, were first reported from sheep in the United States in 1908. The cysticerci were identified in 1913 as the larvae of the dog tapeworms, *Taenia ovis*.

Dr. Doys A. Shorb in 1937 found that the eggs of the broad tapeworm of sheep *Moniezia expansa*, could survive two winters on pasture at Beltsville, MD. In 1938, he was able to confirm the life history of *M. expansa* by feeding five infective tapeworm larvae recovered from as many orobatid mites (*Galumna* sp.) to a parasite-free lamb at different times. One month after the first feeding the lamb was necropsied and two tapeworms whose size corresponded with the feeding dates, were recovered.

In 1939, *Taenia hydatigena*, a tapeworm occurring as an adult in dogs and as a cysticercus in the abdominal cavity of sheep and swine, was found to severely affect sheep in cases of heavy infection. The sheep developed high fever and succumbed from injuries produced in the lungs by the migrating larvae.

Nodular-worm Disease of Sheep—During the winter of 1888-1889, Dr. Curtice discovered the cause of nodular disease of the intestines of sheep, a very prevalent disease in the Southern and Eastern United States. It was commonly mistaken for tuberculosis because the nodules often became filled with cheesy material that later calcified. The cause was found to be the larvae of a previously undescribed nematode, named in 1890 by Dr. Curtice, *Oesophagostomum columbianum*, for the District of Columbia, where he found it. The larval worms eventually escape from the nodules in the mucosa into the lumen of the intestine and live in the colon. There they develop to maturity, producing eggs that pass out of the body of the host in the feces. The nodules also occur on the diaphragm, the parietal wall of the abdominal cavity beneath the peritoneum, superficially on the liver, in the mesenteric lymph nodes, and on the omentum. These observations were published in 1890 in Dr. Curtice's book *The Animal Parasites of Sheep*, a very complete and accurate compendium of information in this field that remained a standard reference for many years.

The Large Stomach Worm—Before Dr. Ransom's investigations of 1905-1906, very little was known concerning the

life history of the common stomach worm of sheep and cattle, *Haemonchus contortus*. Dr. Ransom found that the larvae, after hatching from the eggs in the feces of infected animals, reach their infective stage in 10 days to 2 weeks and are then ready to be taken into the body. The eggs and newly hatched larvae were found to be very easily killed by freezing or drying, whereas, the larvae in the infective stage are highly resistant and can remain alive for long periods of time, even amid very dry surroundings, or when continuously or repeatedly frozen. It was also shown that when the pasture is wet, the infective larvae commonly crawl up grass blades, becoming quiescent when the grass dries, and crawling still higher when the moisture returns. Dr. Ransom found that this upward migration when a film of moisture is present on the grass blades or other objects, characterized the larvae of two other nematode parasites of sheep—*Oesophagostomum columbianum* and *Bunostomum trigonocephalum*, the nodular worm and hookworm. This response to moisture, a favorable one for the parasites, increases their chances of being ingested by a grazing animal. The infective larvae of *H. contortus* when fed to sheep developed to egg-laying maturity in about 3 weeks. These investigations established the main facts of the stomach worm and were the starting point of numerous later studies and experiments in the Zoological Division bearing upon the practical control of this parasite.

Dr. Andrews reported in 1937 that the growth of lambs was slowed by experimental infections with *Haemonchus contortus*, the large stomach worm of sheep, and that the infected lambs required 205 pounds more feed per 100 pounds of gain than uninfected controls. Digestibility coefficients of the two groups were comparable, but there was an apparent decrease in the nonprotein nitrogenous material digested by the infected animals. Sheep heavily infected with this worm died of gastric hemorrhage. Sub-freezing temperatures and drying reduced the number of larvae developing to the infective stage.

Other Internal Parasites—In 1907, Dr. Ransom recorded the results of investigations on the life history of *Strongyloides papillosus*, a common intestinal nematode of sheep which is also transmissible to rabbits. He showed that the larvae that penetrate the skin migrate to the intestine and there develop to maturity. This was the first instance in which the adult stage of a species of *Strongyloides* had been experimentally produced in the intestine as the result of penetration of the skin by the infective larvae. Descriptions were also published of new genera and species of nematodes from cattle, sheep and goats, including: *Trichostrongylus capricola*, *Ostertagia trifurcate*, *O. marshalli*, *O. occidentalis* and *Cooperia pectinata*.

Drs. Ransom and Hall in 1912 described a new nematode, *Ostertagia bullosa*, from the stomach of a sheep. The distribution of some important parasites of sheep and cattle in the United States was outlined by Dr. Ransom, and cysticerci were reported for the first time from the muscles of reindeer from North America.

Dr. Curtice reported from McNeill, MS, in 1930 that treatments consisting of drenches with copper sulphate solution, carbon tetrachloride and tetrachlorethylene, administered at 2-week intervals the year-round, saved 80 percent of the scrub sheep dosed. The 38 surviving sheep gained an average of 60 pounds during the 2-year test, whereas 9 of the 10 untreated sheep died. Weekly treatments with 100 cubic centimeters (cc) of a 1 percent solution of copper sulphate, 5 cc of tetrachlorethylene, or 5 cc of carbon tetrachloride failed to remove all the worms in the treated sheep, but did hold the infection to a low level and did not affect the gestation period of ewes or cause abortion. However, weekly doses of carbon tetrachloride were found to be injurious to sheep, which died 8 to 9 months after treatment began. Beginning in 1931, John Andrews (the writer), then a Junior Zoologist, described and figured the infected larvae of the common nematode parasites of the alimentary tract of sheep to provide accurate drawings that would enable parasitologists to identify the parasites in the sheep by comparing the infective larvae obtained from culturing the parasite eggs in the sheep's feces with the labeled drawings in the manuscript (Dikmans and Andrews, 1933)

In 1938, Dr. Andrews found that the intestinal roundworm *Cooperia curticei* produced nodules in the intestinal mucosa of sheep repeatedly reinfected with the parasites, an expression of the development of resistance by the host to repeated infections. He found under experimental conditions, however, *C. curtecei* did not produce serious pathological lesions in the host animal, but intefered to some extent with the utilization of feed by the host. In contrast, experimental infections with *Trichostrongylus* spp. were very pathogenic: The animals died before the worms reached egg-laying maturity; the condition, therefore, was impossible to diagnose. There was no extensive hemorrhage or anemia in these cases. The pathogenicity of the worms appeared to be associated with marked changes in the guanidine, blood sugar, and non-protein nitrogen in the blood of the infected sheep.

John T. Lucker, parasitologist, was able in 1944 to infect lambs with the hookworm *Bunostomum trigonocephalum* by placing the infective larvae on the skin, but not by feeding them. Uncomplicated infections caused anemia with

accompanying retardation of growth. The extent of the injuries varied with the number of worms harbored. Loss of blood and weight occurred long before the parasite eggs could be found in the droppings, making the accurate diagnosis of the cause of the condition in the living animal impossible.

Kenneth C. Kates and James Turner in 1953 demonstrated the synergistic lethal effect of dual- and triple-species helminthic infections in sheep, and in 1965, Robert Kaight proved that sheep had the capacity to develop resistance to infection with the intestinal thread-necked worm, *Nematodirus spathiger*.

In 1982, J. Ralph Lichtenfels reported the first Maryland case of *Parelaphestrongylus tenuis* in sheep. This nematode is normally a parasite of the lungs and brain of deer and does not cause clinical disease in its normal host. In abnormal hosts, however, it is very pathogenic and has been given as the major reason for the failure of the moose and elk to re-establish themselves in the northeastern United States.

Protozoan Parasites of Sheep—In 1982, John F. Christensen reported that all seven species of coccidia known to parasitize sheep were widespread in the sheep population and that *Eimeria arloingi*, a pathogenic form, occurred in 90 of the 100 samples examined. Under favorable conditions the oocysts sporulated in 2 to 3 days, becoming infective to other sheep, but putrefaction, rapid drying, and prolonged high atmospheric temperatures prevented sporulation and ultimately killed the oocysts. Lambs treated with a dilute solution of copper sulphate and iron sulphate in water passed fewer oocysts, showed milder symptoms, gained weight more rapidly, and were generally in better condition than the untreated controls.

John C. Lotze and Robert P. Leek elucidated the life cycle of the sheep coccidium *Eimeria arloingi* in 1953, and in 1964 showed that intestinal coccidia of sheep develop in locations outside the intestinal tract of goats but do not complete their life cycle. Dr. Lotze discovered in 1972 that day-old lambs were susceptible to coccidial infection. Ronald Fayer and Mr. Leek found in 1979 that the experimental drug salinomycin effectively reduced clinical signs of disease in sheep infected with *Sarcocystis*.

Swine

Trichinosis—Since 1878 the Department of Agriculture has been receiving reports of the presence of trichinae, the larvae of the roundworm, *Trichinella spiralis*, in American pork exported to Europe. In 1879, Italy and Austro-Hungary prohibited the importation of American pork alleging the presence of trichinae. Spain and Germany in 1880, France, Turkey, and Rumania in 1881, Greece in 1883, and Denmark in 1888 also prohibited its importation for the same reason.

By 1880 the livestock industry of the United States had built up a flourishing trade with England and a few countries on the European continent which provided an outlet for our surplus meat as well as a lucrative income for livestock producers. Since the threat of a boycott of American pork was of grave concern to the meat industry, the Department of State, as early as 1881, instituted inquiries to the pork industry with reference to causes that might operate to render pork products dangerous to human health. Accordingly one of the first tasks of the new Bureau of Animal Industry was to determine the extent of *T. spiralis* infection in our domestic hogs. A careful microscopic survey of pork products for trichinae was made in 1884 in Atlanta, Boston, Chicago, Montreal, and Washington. These investigations disclosed that about 2 percent of the hogs from certain sections of the country were infected with trichinae, while hogs from some States were quite free from this parasite. Although, this survey indicated that the danger of contracting trichinosis from eating American pork was being exaggerated by the importing countries, the BAI's Meat Inspection Division in 1892 inaugurated microscopic examination for the detection of trichinae in pork to be exported to countries requiring such inspection.

In March 1898, Charles W. Stiles was sent to Germany as an agricultural and scientific representative in the U.S. Embassy in Berlin to investigate persistent reports that many cases of trichinosis in Germany at that time had resulted from people eating imported American pork. While he was not able to find evidence that cases of trichinosis originated from American pork, he found evidence that demonstrated very clearly the inadequacy of microscopic inspection of pork for trichinae as a prophylactic measure. Microscopic inspection of pork was discontinued in 1906 and regulations were issued that provided for treatment of all pork and pork products intended to be eaten without cooking to destroy live trichinae.

Until Dr. Ransom discovered in 1913 and reported in 1914 that trichinae in pork could be destroyed by refrigeration, the parasites were thought to be unaffected by cold. Dr. Ransom showed that trichinous pork kept at a temperature

of 5°F for 20 days was quite innocuous. Studies were begun in 1914 by Dr. Ransom and Hayes B. Kaffensperger of the Meat Inspection Division, BAI, on curing methods for the destruction of trichinae in pork. These investigations showed that pork products intended to be eaten without cooking that had been refrigerated as noted above, and sausages or chopped meats containing lean fresh pork that had been held under supervision after stuffing during the process of drying for 20 to 25 days in the drying room, were safe for human consumption. In 1919, Dr. Ransom and Benjamin Schwartz established definitely that a temperature of 137°F was ample for the destruction of trichinae. In 1920 and 1921, Dr. Schwartz demonstrated that the vitality of trichinae could be destroyed by massive doses of xrays, and in 1929, he authored a USDA leaflet entitled, "Trichinosis, A Disease Caused by Eating Raw Pork," a very popular publication that has been revised many times as additional information became available.

Dr. Schwartz devised a method in 1930 for preparing trichinae antigen free from muscle tissue and tested it on pigs experimentally infected with trichinae with encouraging results. He also initiated an investigation in 1933 to determine the current frequency of *T. spiralis* infection in swine in the United States. One-hundred-gram portions of the diaphragms of 13,000 farm-raised hogs were artificially digested and the number of larvae per gram of muscle tissue recovered from each diaphragn recorded. Only 0.95 percent of these hogs were found to be infected, most of them with exceedingly small numbers of larvae. Data obtained a few years later from 9,000 hogs fed raw garbage disclosed a trichinae incidence of 6.11 percent. Data from 2,200 hogs fed cooked garbage showed an incidence of slightly less than 0.5 percent. The occurrence of trichinae in nearly 1 percent of the farm-raised hogs presented conclusive evidence that the animals must have had access at one time or another to offal, garbage, kitchen scraps, or possibly such other sources of trichinous meat as mice or rats.

In 1935 a new project was activated at Beltsville to investigate the effectiveness of the current meat inspection procedures designed to kill encysted larvae of *Trichinella spiralis* in pork products, and in 1936 attempts were made to immunize pigs against *T. spiralis*. In 1937, heavy infections with *T. spiralis* were found to produce a significant rise in eosinophilia in pigs, which developed a fever during the acute stage of the infection. Otherwise they showed no symptoms that were diagnostic of the infection and all made uneventful recoveries. The pigs had 840 to 1,215 trichinae per gram of muscle tissue at the time they were killed. Attempts to infect cattle with *T. spiralis* were not successful in producing an infection of the muscle tissue with trichinae, although the experimental animals developed a fever and a stiff gait.

Experiments conducted in cooperation with the Bureau of Home Economics confirmed previous findings that trichinous pork heated to a temperature of 137°F would contain no viable trichinae. Additional studies on the incidence of trichinae in hogs fed raw garbage indicated an infection rate of 3.4 percent, in hogs fed cooked garbage, 0.5 percent, and in hogs fed no garbage, so far as known, 0.32 percent.

A new antigen containing the metabolic products of live trichinae larvae was prepared in 1938 and tested on hogs by the intracutaneous method. Results were more promising than those obtained with earlier antigens.

In 1938 and 1939, investigations of the prevalence of trichinae in hogs confirmed the previous finding that more garbage-fed hogs were infected and harbored heavier infections than grain-fed hogs.

In 1939, only two dead trichinae were found in 11 of 1,200 half-pound samples of frankfurters processed under Federal meat inspection regulations. A basis upon which the freezing period for trichinous meat might be shortened was determined, a new antigen containing finely powdered trichinae was tested and positive results were obtained in 80 percent of the trichina-infected hogs tested. Only lightly infected hogs escaped detection.

Dr. Spindler, in cooperation with O. G. Hankins of the Meats Laboratory of the Animal Husbandry Division, showed in 1944 that the dehydration of pork containing viable trichinae at temperatures of 102°F to 120°F to a 3 percent moisture level would kill all the parasites. If dehydrated at 70°F to the same moisture level, however, the parasites were still alive and infectious, as determined by feeding the dehydrated meat to rats. Two years later Dr. Spindler reported that rapid dehydration of trichinous pork lowered the thermal death point of the parasites, and in 1950 he demonstrated the transmission of *T. spiralis* to swine through the ingestion of feces. In 1951, research scientists at the Beltsville Parasitological Laboratory developed an improved technique for the recovery of encapsulated infective larvae of *T. spiralis* from muscle tissue. Researchers at this laboratory also reported in 1966, that precooling of trichinous pork increased the resistance of the parasites to freezing temperatures.

In 1968-69, Dr. Andrews, of the Beltsville Parasitological Laboratory, D. E. Zinter, of the Consumer Protection Pro-

gram, Consumer and Marketing Service, and N. E. Schultz, of the Animal Health Division, ARS, in cooperation with the livestock and associated industries, tested a pooled-sample digestion technique developed in 1967 by W. J. Zimmermann, of Iowa State University, Ames, IA, designed to facilitate the examination for trichinae of all hogs slaughtered in modern abattoirs with high-speed slaughtering capability. The technique consisted of pooling 5- to 8-gram pieces of diaphragm muscle from 20 to 25 hogs, grinding them in a meat grinder, digesting each composite sample with hydrochloric acid and pepsin in an incubator set at 100°F, and counting the trichinae in the residual that settled to the bottom of the container of each of the diaphragm muscle pools.

Results of the test indicated that this technique was adaptable to a slaughter speed of 460 hogs per hour without interfering with the work flow. Trichina infections detected ranged from less than 0.01 to 641.7 trichinae per gram of diaphragm muscle, and occurred in 42 (0.0087 percent) of the 482,392 hogs examined. The technique could be depended upon to detect as few as 5 trichinae per 100 grams of composite sample at a cost of 9.35 cents per head, or 0.067 cents per pound of dressed pork.

By 1972, R. S. Isenstein had developed a soluble antigen fluorescent antibody test that was capable of identifying 92 percent of garbage-fed hogs naturally infected with *Trichinella spiralis*.

K. D. Murrell of the Animal Parasitology Institute and G. Schad of the University of Pennsylvania, in a major epidemiological study in 1981, provided evidence that swine trichinosis was more prevalent in the swine of the Northeastern States than previously thought.

In 1982, J. Ralph Lichtenfels, using the scanning electron microscope, examined the three "species" of *Trichinella spiralis* that were reported by Russian parasitologists to exhibit the greatest diversity to determine whether there were sufficient morphological differences among them to justify species differentiation. No differences were found. At the International Trichinellosis Commission in Toronto, Canada, Dr. Lichtenfels recommended that the four species names be recognized a subspecies, a compromise that may be acceptable to the Russians, who were present but noncommittal.

Also in 1982, Dr. Murrell, investigating in cooperation with the University of Pennsylvania and others the role of wildlife in the infection of hogs with trichinae, found the incidence of *T. spiralis* infection in Pennsylvania black bears was 4 percent. The overall objective, of course, is to understand the epidemiology of trichinosis.

Dr. Murrell also identified the antigens from *T. spiralis*, using hybridoma-derived monoclonal antibodies. These highly specific antibodies showed that a number of *T. spiralis* antigens were shared with other swine parasites, such as *Ascaris suum*, the large intestinal roundworm of swine, and *Strongyloides ransomi*, a very small roundworm parasite of swine, while some antigens were unique to *Trichinella*. The unique antigens were shown to be components of worm secretory products, a group of proteins known to be a value in diagnostic procedures and animal protection. This project is currently geared to the isolation and characterization of these antigens for eventual incorporation into large-scale production procedures.

In addition, Dr. Murrell has developed improved serological tests in an effort to identify pigs infected with trichinae at the slaughterhouse. One test was rabbit-anti-pig and goat-anti-rabbit antibodies to piggyback on each other to amplify the response of pig antibodies to *Trichinella*. It is hoped that some day such tests may be used at slaughterhouses to make it possible to have pork that is certified to be *Trichinella*-free.

K. D. Murrell and R. H. Gamble, of the Animal Parasitology Institute, have developed an enzyme-linked immuno-sorbant-assay test (the ELISA test) for the diagnosis of swine trichinosis, using an antigen purified by monoclonal antibody immuno-purification. They have initiated, and are carrying out, a nationwide epidemiological study on the role of infected wildlife and farm rats in the transmission of *T. spiralis* to swine. They are developing a vaccine for the control of swine trichinosis and are working on the isolation and identification of enzymes secreted by larval and adult *T. spiralis* for possible use as antigens and also are working on the determination of the biological efficacy of Cs'37 irradiation for the devitalization of trichinae in pork.

Dr. Isenstein, currently a staff officer of the Serology Branch, Pathology and Epidemiology Division of the Science Program of the Food Safety and Inspection Service, USDA, is carrying on research on the development and evaluation of immunodiagnostic systems for use in the field (abattoirs, clinical laboratories, and farms) for the mass diagnosis of trichinellosis and other parasitic conditions, with the aim of prohibiting potentially harmful meat or meat products from reaching the consumer market.

Ascaris suum—In 1917, Dr. Ransom discoverd that *Ascaris suum*, the large intestinal roundworm of swine, did not require an intermediate host to complete its life cycle. He also found that ascarid larvae may cause a serious and often fatal pneumonia, called "thumps," in the course of their migration through the lungs of young pigs. The next year he became convinced that by keeping the sows clean just before and after farrowing and by providing clean surrondings for the young pigs, one might be able to prevent them from becoming infected with parasites.

Dr. Ransom began experiments in McLean County, IL, in 1919 to determine the extent to which sanitary measures would prevent ascarid infection in pigs. He appointed Hayes B. Raffensperger, of the Meat Inspection Division of the BAI, in Chicago, to head the project. At about this time, Dr. Schwartz discovered a blood destroying substance in the roundworm, Ascaris lumbricoides, a parasite of man and a close relative of the swine ascarid.

In 1921, Dr. Ransom published detailed studies on the migration of ascarid larvae in the body of the hog, and the moving picture entitled, "Exit Ascaris," was made and shown. Two years later, Dr. Ransom published a paper on the McLean County System of Swine Sanitation for the Control of Swine Parasites, and Dr. Schwartz demonstrated pronounced ill effects of a pseudo-anaphylactic nature resulting from his studies of the toxic effect of *Ascaris* fluid on man. *Ascaris* eggs were also found to be quite resistant to strong lye solutions, indicating that the larva inside would be difficult to kill.

Charles H. Hill developed a mechanical apparatus in 1960 to facilitate the separation of *Ascaris* and *Trichuris* eggs from swine feces. In 1969, Drs. Douvres, Tromba, and Lichtenfels completed definitive redescriptions of the life cycle and morphogenesis of *Ascaris suum*, both *in vitro* and in the normal host. They showed that spontaneous elimination of the parasite from the pig intestine occurred in association with the third larval molt. A previously known elimination at about 25 days after infection had been associated with the fourth larval molt. Since the worm substance for these two molts may not be stage specific, these findings may have wide application to other parasitic species. In 1969, W. R. Anderson, the Institute's bacteriologist, identified the microbian flora associated with *Ascaris*. In 1971, Mr. Anderson characterized the cuticular lesions of *Ascaris suum* histologically and identified certain associated microorganisms. He also established criteria for evaluating the development of *A. suum* in laboratory animals commonly used as experimental hosts.

In 1979, F. G. Tromba discovered that ultraviolet-irradiated eggs of *A. suum* showed promise as a vaccine for controlling infection with this large intestinal roundworm of swine. Three doses of *Ascaris* eggs attenuated by ultra-violet light irradiation provided the immunized pigs more than 80-percent protection against live infection. Work is in progress to increase this level of immunity and to make the immunization procedure more practical. A vaccine is being considered as an alternative control measure since chemotherapy has failed to control this parasite adequately.

Patricia A. Pilitt and Dr. Lichtenfels in 1980 described the morphology of late fourth-stage and early adults of *A. suum* using light and scanning electron microscopy. This study completes the description of all developmental stages of *A. suum*. The new information will permit rapid and reliable differentiation of larval and adult stages in efficacy tests of control agents.

Frank Douvres in 1970 was able to cultivate the larvae of *A. suum* to the fourth-stage, *in vitro*, but could not get development to the fifth-stage, the adult worm.

In 1979, J. F. Urban reported the development of a culture procedure for *Ascaris suum* larvae and swine lymphocytes that will permit the study of the role of lymphocytes in the production of immunity to that parasite.

By 1980, Dr. Douvres succeeded in culturing *A. suum, in vitro*, in a chemically defined medium, i.e. one in which all the ingredients were known. The worms were found to excrete antigens into this medium, a finding that will greatly facilitate the isolation and characterization of this parasite's important antigens—a necessary step in the development of a vaccine. In 1983, Drs. Douvres and Urban reported that in a three-step roller culture system, second-stage larvae of *A. suum*, artificially hatched from eggs, developed in large numbers to the fourth stage, and a few developed to young and mature adults. Two mature females that produced unfertilized eggs and a mature male with spermatozoa were the most advanced stages attained. The mature females were obtained in 67 and 73 days and the largest female measured 110 mm. From days 67 to 125, the female produced 1,356,000 unfertilized eggs. The mature male was obtained in 80 days and measured 77 mm long. It had paired spicules that were 1.5 mm long.

The Swine Kidney Worm—The swine kidney worm, *Stephanurus dentatus*, was first reported in the United States

in 1900. In 1927, studies of its life history indicated that the so-called, "parasitic livers" of swine were due to some extent to kidney worms, resulting from their migrations in the body of the pig and development of the larval forms in the liver. It was not until 1929 that Drs. Schwartz and E. W. Price ascertained the essential facts concerning its life history and found that the infective larvae enter the host by penetrating the skin.

Dr. Schwartz in 1932 reported on practical control measures for the swine kidney worm in the South. In 1937, Drs. Schwartz and Price demonstrated its life history. They found that the infective larvae could survive on unshaded soil for about 2 months and on shaded soil or at the base of grass approximately 3-½ to 4 months. They found that the worms produced small ulcers in the gastric mucosa and caused lesions in the liver of infected pigs. Infection of the pig was controlled by strict adherence to the swine sanitation system, described earlier.

Dr. Tromba found in 1953 that earthworms could act as paratenic hosts for the larvae of the swine kidney worm. In 1962, Drs. Douvres and Tromba, cultivated *S. dentatus* to the fourth stage on swine kidney cell tissue cultures. In 1963, Drs. Tromba and Baisden characterized the antigens and antibodies involved in the serological tests for the diagnosis of kidney worm infections in swine. The next year, Drs. Tromba and Baisden established the fact that cells of the excretory gland in the kidney worm were the principal source of antigen production. In 1969, W. R. Anderson identified the microflora associated with the swine kidney worm. In 1970, Romanowski and Marcia L. Rhoads presented a paper at the Second International Congress of Parasitology, Washington, DC, reporting the results of studies indicating that the excretory gland cells of *S. dentatus* have a secretory function. Granules found in these cells resembled the secretory granules of various exocrine and endocrine glands. The granules were eosin and PAS positive and did not contain glycogen, acid mucopolysaccharides, and lipids. They were thought to contain glycoprotein, and their presence led to the postulation that the excretory gland cells have a secretory function. This announcement was followed in 1971 by a paper by Dr. Romanowski, D. E. Thompson, and P. A. Madden reporting the same findings. It was hypothesized that the proteolytic and estrolytic enzymes and hyaluronidase found in the gland cells may be utilized by the worm in its migration through host tissues and information of the fistula between the cyst surrounding the worm and the lumen of the ureter, permitting eggs to be released into the urine and allowing the nematode to complete its life cycle. In 1973, hydrolytic enzymes were found in extracts of the excretory gland cells of *S. dentatus* by Dr. Romanowski, L. Rhoads, and G. M. Malakatis.

In 1972, Drs. Lichtenfels and Tromba completed the definitive redescription of the life cycle and morphogenesis of the larval stages of *Stephanurus dentatus* in order to enhance the research effort directed toward the development of a protective vaccine against the nematode. In 1973, Mr. Anderson and Dr. Tromba identified the micro-organisms associated with *S. dentatus* and the parasitized tissues of swine, and Drs. Tromba and Romanowski in 1976 developed an experimental vaccine for the control of the swine kidney worm.

In 1978, Mr. Anderson found that the vaccination of swine with a strain of *Streptococcus faecalis* isilated from *S. dentatus* did not affect subsequent nematode infections but did modify the microflora usually found associated with swine kidney work larvae migrating in the tissues of infected animals. In the same year, Dr. Romanowski's studies were found to support the hypothesis that the excretory gland cells of *S. dentatus* have a secretory function and indicated that the ribonuclease (RNase) isolated from these cells had a pyrimidine base specificity and was similar to pancreatic ribonuclease. These cells, therefore, may be the source of protective antigens. The excretory glands of adult male *S. dentatus* had 20 times as much acetylocholinesterase activity as females and secreted this enzyme into the maintenance medium: the females did not do this. Its relation to antigenic activity is under investigation.

In 1982, Dr. Romanowski's studies gave support to the hypothesis that the excretory gland cells of *S. dentatus* indeed had a secretory function and indicated that the RNase he isolated and purified from the excretory gland cells was active and hydrolized yeast RNA, cyclic nucleotides, and polynucleotides. Analysis of the byproducts of the hydrolysis indicated that *S. dentatus* RNase should be classified as an endoribonuclease.

Experimentally infected pigs produced antibodies against the RNase. The RNase was also secreted by adult worms into an *in vitro* maintenance medium and may function in the worm to degrade RNA as a source of nucleotides for metabolic purposes.

Dr. Romanowski also found that the excretory gland cells of *S. dentatus* had the highest levels of DNA-ase activity when compared with other worm organs. This was important evidence that the so-called excretory gland had a secretory function. Mrs. Marcia L. Rhoads purified acetylcholinesterase, an enzyme present in unusual amounts in *S. dentatus*, and its physico-chemical characterization was achieved. Also, Dr. Tromba made the surprising observation during

a histo-pathological study of swine tissues infected with larval *S. dentatus* that intimate contact with large numbers of inflammatory cells appeared to have little adverse effect on the parasites. Parasite-mediated modulation of the host's defensive response may be the reason.

Other Worm Parasites of Swine—According to U. G. Houck, the larvae of the May and June beetles, *Phyllophaga spp.* and *Cotina nitida*, were first reported in 1892 as the intermediate hosts of the thornheaded worm of swine, *Macracanthorhynchus hirudinaceus*, in the United States. In the same year, Drs. Hassall and Stiles described a new swine stomach worm, *Strongylus rubidus (Hyostrongylus rubidus)*, in this country. The rarity of *Taenia solium*, the pork tapeworm of man, in the United States was reported in 1895. In 1898, Dr. Stiles published an important paper on the flukes and tapeworms of swine, along with those of cattle and sheep, with special reference to meat inspection. Studies on the muscle fluke of swine, *Agamadistomum* sp., and on a lung fluke of swine, *Paragonimus westermani*, were published in 1900.

Dr. Ransom reported the presence of swine hookworm, *Crassisona urosubulatum*, in the United States for the first time in 1921, and that the dog and sheep hookworms, *Uncinaria stenocephala* and *Bunostomum trigonocephalum*, respectively, had been recovered from pigs. Dr. Schwartz described the hemolytic effects of toxins from parasitic worms in 1921.

Dr. Hall described the eggs and larvae and Dr. Ransom, the adult worm parasites of swine in 1922, and Dr. E. A. Chapin described a new gullet worm, *Gongylonema ransomi*, from American swine. The Meat Inspection Division immediately instituted measures to remove this parasite from hog tongues.

Dr. Schwartz in 1926 reported finding a nodular worm, *Oesophagostomum longicaudum*, in swine in the United States and the Phillippines and said that it had recently been reported from New Guinea.

Drs. Schwartz and J. E. Alicata reported in 1929 the occurrence of a parasite of swine belonging to the genus *Strongyloides* that was quite pathogenic to pigs. It appeared to be a separate species from the *Strongyloides* occurring in sheep and they named it *Strongyloides ransomi*. In 1930, Dr. Schwartz reported finding two new species of nodular worms from swine in the vicinity of Moultrie, GA. They were named by Schwartz and Alicata *Oesophagostomum brevicaudum* and *O. georgianum*.

In 1930 earthworms were found to ingest swine lungworm larvae, enabling the latter to survive in otherwise lethal environmental conditions for several months.

One species of nodular worm predominated in the fall and winter months and produced severely inflamed lesions in the cecum, while the other predominated in the spring months and produced mild lesions.

During the 7 years beginning with 1933, the following advances were made: Dr. Spindler described the life cycle of *Oesophagostomum longicaudum*, a nodular worm of swine in 1933; Mr. Lucker reported on the development of the swine nematode *Strongyloides ransomi* and described the behavior of its infective larvae in 1934; Drs. Schwartz and Alicata published a paper describing the life history of the lungworms parasitic in swine in 1935; Dr. Alicata described the early developmental stages of nematodes occurring in swine in 1936; Dr. Spindler found, in 1937, that suckling pigs acquired helminth infections during the first 3 weeks of life; and in 1938, he reported that swine lungworms may survive in earthworms for at least 4 years.

In 1939, swine lungworms were found to remain viable outdoors on moist soil at Beltsville, MD, for 3 years and infected earthworms retained infective larvae for a similar period. Pigs were found to be more susceptible to infection with lungworms when their stomachs were empty than when they were full. Also in 1939, the true June beetle (*Lachnosterna*) was found to be capable of surviving infection with the larvae of the thorn-headed worm, *Macracanthorhynchus hirudinaceus*, whereas other lamellicorn beetles subjected to infection with the parasite died. Adult beetles that survived the infection remained a potential threat to hogs which swallowed infected beetles.

In 1941, Dr. Spindler reported for the first time that myocardial involvement caused the sudden death of pigs infected with *Strongyloides ransomi*. In 1942, Kenneth C. Kates ascertained the pathogenicity of thorn-headed worm infections and determined that the eggs of the parasite would remain viable at Beltsville as long as 3-½ years. The economic effect of parasitic infections in pigs was demonstrated in 1948 by Dr. Spindler. Charles H. Hill reported in 1955 that the eggs of *Trichuris suis*, the whipworm of swine, survived on pastures at Beltsville for at least 6 years. In 1959,

the transmission of the rodent nematode *Hepaticola hepatica* to swine was demonstrated, a finding that suggested a possible route of infection from rodents to man.

In 1980, K. D. Murrell detected cuticular antigens associated with the surface of *Strongyloides ransomi*, the causative agent of porcine strongyloidiasis, through the application of immunochemical techniques. Work is presently under way to isolate these antigens and to evaluate their potential as vaccines.

Also in 1980, Marcia L. Rhoads elucidated the basic biochemistry of important swine nematode parasites and demonstrated for the first time the secretion of proteinase inhibitors by any parasite.

Protozoan Parasites of Swine—In 1939, the study of the intestinal ciliated protozoan parasite *Balantidium coli* demonstrated that piglets can acquire infections with this parasite at the age of 2 to 3 weeks, that the production of cysts is associated with the presence of solid material in the feed, and that heavy infections may be accompanied by frequent attacks of diarrhea which are short-lived. A diet of cow's milk eliminated the infection, but it returned when the diet included solid feed.

Experimental infection of 4 to 8-week-old pigs with coccidia belonging to the species *Eimeria debliecki* and *E. scabra* showed that the incubation periods of these two species were 6 and 9 days, respectively. In the absence of reinfection, the infections lasted less than 3 weeks, and the outstanding symptom was marked emaciation.

In 1943, *Sarcocystis* was experimentally transmitted to swine by the ingestion of their own feces and urine 15 days or more after they were fed meat containing Miescher's Sacs. The next year *Sarcocystis* infection in swine was found to be propagated by rodents, cats, dogs, and chickens, as well as by pigs.

Paul R. Fitzgerald, E. A. Johnson, J. L. Thorn, and D. M. Hammond in 1955 found that nasal trichomonads from swine could cause abortion in cattle. In 1956 David Doran elucidated the metabolism of a *Trichomonas batrachorum*-type flagellate from the cecum of swine, and Francis Harl of the Pathological Division and John Andrews of the Animal Disease and Parasite Research Division, ARS, demonstrated that nasal trichomonads of swine had no causal relationship to atrophic rhinitis in swine.

Swine Parasite Control on Southern Farms—In 1925, the original McClean County Swine Sanitation Project was undergoing its final evaluation. Early in that year, the manager of the Swift & Company packing plant in Moultrie, GA, and personnel of the Zoological Division informally discussed the possibility of establishing a laboratory in the area to develop methods for controlling swine parasites on hog farms in the Coastal Plain area of Georgia. As a result of these talks, Swift agreed to build a laboratory on its Moultrie property and to cooperate with the division in carrying out a research program. Work was begun in Georgia on July 1, 1925, on a project to determine if the McClean County system for swine parasite control could be applied as effectively on hog farms in the South as it was in Illinois.

Dr. Erasmus M. Nighbert, who had been in charge of sheep parasite work in Queen City, MO, was transferred to Moultrie to take charge of the swine parasite program. The work started in July 1925 on the farm of W. W. King, who was paid $50.00 a month for allowing the division to manage a portion of his herd of purebred Duroc Jersey swine with whatever scheme the Bureau desired to have tested. Other cooperators, unpaid, were added by Dr. Nighbert. These were of two kinds: One exercised a moderate degree of sanitation, based largely on the McClean County system; the other (the control) managed herds in the usual fashion—with no sanitation.

Dr. Nighbert had an excellent reputation as an entertaining public speaker, having had many years experience discussing animal disease and parasite problems with farmers and veterinarians at home and abroad. On one occasion he was asked by one of his friends to give a talk at a prayer meeting at a church in Moultrie. He agreed to do this and at the appointed time and to the surprise of everyone he gave them a pep talk on hog worms and how to prevent infections by means of the swine sanitation system. Nobody present ever forgot this momentous occasion.

By 1927, the swine sanitation system was proved to be effective in reducing the parasite burden of young pigs in the South.

In 1929, Dr. Cram reported that shrikes, which are carnivorous birds, become infected with larvae of the swine stomach worm, *Physocephalus sexalatus*, when they eat dung beetles infected with these parasites. The larvae become encysted in their intestinal mucosa and when fed to pigs the larvae develop into adults.

Early in the 1930's it became apparent that cooperative work with farmers had its limitations. So Dr. Schwartz, who was division chief, S.H. Starr, director of the Coastal Plain Experiment Station, Tifton, GA, and Byron Southwell, animal husbandman at the experiment station, held a number of conferences during which they discussed the possibility of transferring the swine parasite work to Tifton. The main reasons for the transfer were as follows: (1) The lack of facilities at Moultrie to carry on experimental work; (2) the lack of experimental animals that should be necropsied when required by the experiment; and (3) the need for controlled conditions when conducting research on effects of parasites on the nutrition and growth of swine.

Shortly after July 1, 1941, the laboratory was moved to the Coastal Plain Experiment Station, Tifton, and a laboratory was set up in the basement of the station's original research building. On August 1, 1941, John S. Andrews assumed the duties of parasitologist in charge of the Parasite Laboratory. In 1951 the laboratory was moved to the recently completed Animal Disease Laboratory on Brighton Road. After this move, some research effort was directed to aiding State personnel in diagnosing parasitism in animals submitted for necropsy.

Publications resulting from work at these locations covered many different parasite of swine and many ways to control them. The main theme was swine sanitation, which paid off handsomely: Georgia farmers reported marked savings in feed costs, heavier market weight of pigs, and fewer pigs with parasitized livers and kidney fat when they used the McClean County system of swine sanitation on their farms.

New information was obtained at the Tifton laboratory about the swine kidney worm, *Stephanurus dentatus*, about how its larvae could enter the pig through the skin. This parasite also was found in a calf. Also at the Tifton facility, several new species of swine parasites were discovered and the life history of the swine nodular worm, *Oesophagostomum longicaudum* was elucidated. Dale A. Porter described new intermediate hosts of the swine stomach worms *Ascarops stronylina* and *Physocephalus sexalatus*. Drs. Nighbert, Raffensperger, Spindler, and Swanson contributed papers to the literature on parasites during the early years of this work in Georgia. After 1941, Dr. Andrews, T. Bonner Stewart, Francis G. Tromba, W. W. Becklund, O. G. Marti, and W. N. Smith were the investigators at Tifton. The Tifton Laboratory was closed during the 1982 fiscal year.

Horses

Helminth Parasites—Following is a chronology of work on helminth parasites of horses:

1907 - Dr. Ransom reported for the first time in horses in the United States a very small pinworm of equines, *Probstmyaria vivipara*, that gives birth to living larvae and can complete the life cycle within the confines of its host's intestine.

1911 - Dr. Ransom was the first scientist to determine the life history of the horse stomach worm, *Habronema muscae*. Its larvae had been described from the common house fly, *Musca domestica*, by Carter in India in 1861, but their significance remained unknown for 50 years. Dr. Ransom found that these nematodes in the fly were larval stages of *Habronema musca*. He discovered that the maggots of house flies in the manure of infected horses ingest the eggs of the parasite and the larvae develop within the bodies of the maggots, reaching a stage at which they are ready to be transferred to the horse at about the time the fly transforms from the pupa into the adult. The young worms collect commonly in the proboscis of the fly and escape in the presence of warmth and moisture, as, for example, when a fly is sucking moisture from the mucous membranes or from abrasions on the skin of a horse. Horses also swallow many flies and fly pupae, which are common in the chaff in the bottom of mangers, and in this way also swallow the nematodes, which thus reach their final host in whose stomach they develop to maturity.

1918 - Drs. Ransom and Hadwin reported for the first time that the horse stronglye, *Triodontophorus tenuicollis*, was the cause of ulcers in the large intestine.

1923 - Dr. Hall published a paper on the diagnosis and treatment of diseases caused by the internal parasites of horses and discussed the relation of the life histories of the parasites to the treatment given to remove them.

1928 - Dr. Schwartz found that the eggs and larvae of the gastro-intestinal roundworm parasites of horses could be killed if the heat generated by the fermentation of the manure could be confined and allowed

to build up in the manure pile. Horse manure kept in an insulated box for one week generated enough heat to destroy the vitality of parasite eggs and larvae present in it, but the infective larvae of these parasites were markedly resistant to cold, surviving -36°F for long periods. These larvae were found to be still active in manure exposed to weather conditions in Montana after almost two years. Cooperative work with the owner and his representative, on a farm near Lexington, KY, demonstrated that a combination of treatments for the removal of parasites from horses together with sanitation on pastures and in barns, resulted in a marked decrease in infection as compared to that noted in previous years.

1929 - The occurrence of a roundworm parasite belonging to the genus, *Strongyloides*, was reported for the first time in horses in Kentucky and possibly for the first time in American horses. (This parasite was again reported from a horse in Mississippi in 1946.)

1930 - Drs. Schwartz, Imes, and Wright, were joint authors of a paper on the parasites and parasitic diseases of horses and their control. Three years later Dr. Everett E. Wehr described the life history of the horse bot, *Gastrophilus intestinalis*, and the lesions produced by its larvae in the stomach.

1932 - Dr. Hall described and published sketches of the eggs and larvae of horse parasites, as well as those of the other domestic animals, to enable practicing veterinarians to make their own diagnosis of parasitic conditions they might encounter. In the same year 12 species of nematode parasites of horses were reported for the first time in the United States, four by Miss Cram:

> *Cylicostomum auriculatum, C. euproctus, C. goldi*, and *Oesophagodontus (Strongylus) robustus*;

and eight by Dr. Maplestone, an English parasitologist, who found them in horses imported from the United States:

> *Cylicostomum coronatum, C. longibursatum, C. minutum, C. nassutum* var. *parvum, C. pseudocatinatum, Cyalocephalus equi, Triodontophorus brevicauda*, and *T. tenuicollis*.

1937 - Research on horse parasites indicated that deep plowing appeared to reduce the availability of infective strongyle larvae to grazing animals on infested pastures and horse urine was found to contain a lethal factor that killed horse strongyle larvae before they hatched from the egg. Also, Mr. Lucker and Dr. Schaeffer found that exposure of eggs and preinfective larvae of horse strongyles in horse manure to carbon tetrachloride, ethylene dichloride, a mixture of the two, and a preparation of dichloropentanea, in separate closed containers destroyed the vitality of the eggs and preinfective larvae but failed to kill all of the infective larvae.

1938 - Experiments conducted by Mr. Lucker on the control of horse parasites showed that complete devitalization of the eggs and larvae of the roundworm parasites of horses required a temperature of at least 95°C for at least 30 minutes, conditions that could easily be met by storing the manure in a doublewalled box. A mixture of isomeric dichloropentanes in the proportion of 5 to 12.5 cubic centimeters of chemical per pound of manure killed the eggs and preinfective larvae of these parasites exposed to the chemicals for 30 hours to seven days.

1939 - Mr. Lucker reported that alternate freezing and thawing of horse manure was fatal to contained parasite eggs, provided the period of thawing was long enough to permit appreciable development of the eggs and freezing was of sufficient duration and intensity to kill the developing embryos.

1975 - Kenneth C. Kates, Merle Colglazier, and Frank D. Enzie found that oxibendazole was a very satisfactory anthelmintic for the control of helminth parasites of equids.

1980 - Dr. Lichtenfels and colleagues found that the deaths of horses in Indiana and Florida were caused by filarid and spirurid nematodes. All previous United States cases were believed to be due to *Strongylus* larvae. The new records may reflect improved diagnostic capabilities, rather than new nematodiases.

1982 - Dr. Lichtenfels reported the first North American case of cerebrospinal nematodiasis in a horse due to a filarid nematode. The parasite was *Draschia megastoma*.

Protozoan Parasites—The first investigations of the parasites and parasitic diseases of horses by the new Bureau of Animal Industry were published in 1884 and were concerned with an outbreak of glanders, a disease caused by a protozoan, *Trypanosoma equiperdum*. In 1902, the Zoological Laboratory issued an emergency report on Surra, a blood disease of horses and other domestic animals, which also is caused by a protozoan parasite, *Trypanosoma evansi*.

Not until 1964 was research on the protozoan diseases of equines put on the agenda of the Beltsville Parasitological Laboratory of the Animal Disease and Parasite Research Division, ARS. Dr. A. A. Holbrook identified the tropical horse tick *Dermacentor nitens* as the intermediate host for the transmission of equine piroplasmosis (Babesiosis) in the United States. Dr. Holbrook in 1965 developed an improved antigen for the diagnosis of equine Babesiosis at Beltsville that, when combined with the corresponding antibody, fixed complement satisfactorily. In 1967, Dr. Holbrook was able to show that animals with equine piroplasmosis remained "carriers" of the disease organism *Babesia caballi* and sources of reinfection for at least 2 years after all symptoms of the disease had disappeared. In 1968, Drs. Holbrook and Frerichs showed that ticks harboring *B. caballi* were free of the parasites after living for two generations on cattle. This indicated the possibility of developing a nonchemical control of the disease by pasturing cattle on affected areas in sufficient numbers and for an adequate period of time for the ticks to develop through two generations on cattle.

Wayne Frerichs and Dr. Holbrook developed serologic tests to detect and differentiate *Babesia caballi* and *B. equi* infections in horses and provided protocols to diagnostic laboratories around the world in 1969 for the production of the CF antigen for use in diagnostic tests to detect equine piroplasmosis.

In 1970, Drs. Holbrook and Frerichs determined the life cycle of *Babesia caballi* in its vector, the tropical horse tick, *D. nitens*. In 1972, Drs. T. O. Roby, A. A. Holbrook, and others showed that *B. caballi* multiplied in the tick vector and that the tick, therefore, was more than a passive transmitter of the disease agent: It was a true biological intermediate host. Frerichs and colleagues discovered in 1972 that the experimental drug imidocarb was highly effective for the elimination of *B. caballi* infections in horses. Research scientists at API in 1978 showed that extracts of tropical horse tick eggs from females infected with *B. caballi* were infective to horses. This was the first recorded transmission of a piroplasm not associated with tick salivary glands and suggested that there is a fundamental difference between *B. caballi* and certain bovine Babesias and that the developmental stage of *B. caballi* in the salivary gland may be significant only because its location there ensures access of the parasite to the host by tick bite. *B. caballi* was also found to be transmitted by the winter tick (*Dermacentor albipictus*). Since this tick is widely distributed, the potential hazard to the American horse population is greatly increased. This finding added urgency and importance to controlling the importation of carrier horses into the United States.

K. L. Kuttler reported in 1979 that a new adjuvant ((2096), Pfizer) was used with a *Babesia equi* antigen and found to elicit a strong serological response almost equal to that produced by Freund's Complete adjuvant, but without the severe local tissue reactions. The next year Dr. Stiller showed that the winter tick, *D. albipictus*, which occurs commonly throughout the United States, was a natural vector of equine piroplasmosis, even when the ticks were held at a temperature of 9°C to 18°C, which approximates conditions during the tick's natural winter cycle.

Poultry and Game Birds

Helminth Parasites—The first Annual Report of the Bureau of Animal Industry for the year 1884, contained Theobald Smith's translation of a memoir on gapeworm disease of fowls by a French parasitologist, J. P. Megnin. The Animal Report for 1885 contained a report of some experiments showing that earthworms were not necessary intermediate hosts of the fowl gapeworm, *Syngamus trachealis*. In the course of these experiments, a parasite was seen in the mucous lining of the crop of a chicken, but was not studied in detail. Reports of tapeworms of chickens were published in 1896.

Dr. Ransom in 1904 described a new species of *Gongylonema* (*G. ingluvicola*) which occurred in the crop wall of chickens, apparently the same species as the worm observed in the crop lining of a chicken in 1885. Dr. Ransom also reported the eye-worm, *Oxyspirura mansoni*, for the first time from American chickens. A new nematode, *Strongylus quadriradiatus* (Stevenson, 1904) was described as a cause of losses among pigeons, and *Davainea echinobothrida*, a tapeworm, was shown to be the cause of nodular taeniasis of the intestines of American chickens.

Dr. Ransom, in 1920, reported the results of his 5-year study of the poultry gapeworm, *Syngamus trachealis*. He found that adult turkeys were commonly infected with the parasite in localities in which the parasite was absent from adult chickens, and as chickens were susceptible to infection only while very young, they became infected from tur-

keys carrying the mature parasites. These studies have shown that the most serious gapeworm trouble occurred among chickens when they were associated with turkeys, and that in the absence of turkeys the parasite was unlikely to be troublesome and tended to disappear. It was also found that in turkeys the gapeworm commonly grew to nearly twice the size that it attained in chickens, which was in accord with other evidence that the turkey was a more favorable host than the chicken. This was the year that Miss Eloise B. Cram, who was later placed in charge of research on the internal parasites of poultry and game birds, joined the division. Before coming to Washington, she had been working in the laboratories of Armour and Company, meat packers in Chicago, and came as a result of Dr. Hall's suggestion that she might like to apply for a position in the Zoological Division.

In 1922, Dr. Hall published a paper describing the eggs and larvae of poultry parasites, and in 1925, Dr. Schwartz reported that American chickens were parasitized by *Ascaridia lineata*, an intestinal roundworm known to be present in European chickens, and that the larvae of the roundworm, *Heterakis beramporia*, caused intestinal nodules in chickens.

Eloise Cram's Ph.D. thesis, entitled, "Bird Parasites of the Nematode Suborders: Strongylata, Ascaridata and Spirurata," was published in 1927. Dr. Cram's continuing studies of poultry parasites brought to light a new species of *Echinuria*, (*E. decorata*) markedly pathogenic for geese, and a new gapeworm, also causing numerous fatalities among geese. The pathogenic nematode *Capillaria annulata* was found in additional outbreaks of parasitic ingluvitis (inflammation of the crop) of birds. A survey of parasites of chickens and other birds in Georgia and Mississippi disclosed some new pathogenic species and new hosts.

In 1928, Dr. Cram participated in cooperative investigations with the Bureau of Biological Survey demonstrating that many of the tapeworms parasitic in quail were the same species as those found in chickens, and that quail, therefore, could be a source of infection to domestic poultry.

Myrna F. Jones, a junior zoologist, found in 1928 that dung beetles were intermediate hosts of the tapeworms *Hymenolepis carioca* and *Raillietina cesticillus* of chickens, and for the first time reported that the thornheaded worm, *Plagiorhynchus formosus*, was a parasite of American chickens and robins. Everett E. Wehr began a study of the parasites of migratory waterfowl in Miles City, MN, and Dr. Cram reviewed the present status of our knowledge of poultry parasitism in 1928.

In 1929, many facts were brought to light by the researchers working on poultry parasites. Miss Jones found four species of snails that were intermediate hosts of the poultry tapeworm *Davainea proglottina*. Dr. Cram demonstrated for the first time ever that grasshoppers could be intermediate hosts of nematode parasites of poultry and wild birds, conveying such parasites as the proventribular worm, *Tetrameres americana*, of gallinaceous birds, the gizzard worm, *Cheilospirura spinosa*, of the ruffed grouse and bobwhite quail, and *Aquaria anthuris* of crows. She also found that dung beetles were intermediate hosts of the spirurid *Gongylonema ingluvicola* of poultry. The life histories of these five nematodes had not been previously known.

Research in cooperation with the Bureau of Biological Survey in 1929 discovered 16 species of parasitic nematodes of quail (15 of which were previously unknown from quail). Dr. Cram described a new nematode of chickens of the genus *Strongyloides* (*S. avium*), a genus not previously known as parasitic in birds. Certain species of sow bugs were found to be intermediate hosts for a nematode (Dispharynx spiralis) that occurs in the glandular stomach of gallinaceous birds, and cockroaches were incriminated as intermediate hosts for the nematode *Seurocyrnea colini*. The cross-transmission of seven species of nematodes from one species of bird to another was accomplished; a new species of tapeworm, *Raillietina* (*Paroniella*) *magninumida*, from the guinea fowl was found to develop in a ground beetle, while three additional species of ground beetles and one additional species of dung beetle, a common pond snail, and a grasshopper were found to be intermediate hosts of poultry tapeworms. A monostome cercaria was found to be the larva of a fluke parasitic in the ceca of domesticated ducks.

In 1930, Dr. Cram described the life histories and pathogenicity of the roundworm parasites of poultry and reported that wild birds in Montana, North Carolina, and Virginia harbored natural infections of nematodes which were pathogenic for domestic birds.

In 1933, Dr. Cram described the development stages of some spirurid nematodes of poultry and game birds, and with Miss Eugenia Cuvillier, a junior zoologist, published a paper on the nematode parasite of pigeons *Ornithostrongylus quadriradiatus* and its treatment. Marked differences were found in the fauna of the ruffed grouse of the interior of Labrador and that of grouse living and mingling with domesticated birds. Only one worm, *Heterakis gallinae*, of wild

birds made its appearance in turkeys in Montana, and the ring-necked pheasant was considered to be the source. Blackhead appeared at the same time as the roundworm. The cockroach was discovered to be an intermediate host of the poultry roundworm *Tetrameres americana*, and cross-transmission of nematodes from one species of bird to another was effected in three instances. Several new species of parasites were found in the wild birds examined, but the only really new one was *Ascaridia numida*, a roundworm, reported for the first time. Dr. Cram also found two more species of ground beetles that were intermediate hosts of the poultry tapeworms *Raillietina cesticillus* and *Amara* sp. and of *R. magninumida* of the guinea fowl.

Results of studies on the parasites of quail were included in a book by H. L. Stoddard of the Bureau of Biological Survey, on the bobwhite quail, its habits, preservation, and increase, published in 1931.

In 1932, Allen McIntosh described some new species of trematode worms of the genus *Leuchloridium* Caras, parasitic in birds from northern Michigan, with a key and notes on other species of the genus, and Dr. Cram brought our knowledge of poultry parasitism up to date. In 1933, a second paper by Dr. Cram and Miss Cuvillier was published on a parasitic disease of pigeons called ornithostrongylosis, caused by an intestinal roundworm, *O. quadriradiatus*.

Myrna Jones and J. E. Alicata in 1935 described the development and morphology of the cestode, *Hymenolepis cantaniana*, in coleopteran and avian hosts.

In 1936, Dr. Cram described a new species of *Strongyloides* in chickens in Puerto Rico which she named, *Strongyloides avium*, and Dr. Allen found a new coccidium which caused lesions in the intestine of young Pekin ducks that often were fatal. Drs. Jones and Horsfall reported that two species of ants were intermediate hosts for poultry tapeworms *Raillietina echinobothrida* and *R. Tetragona*.

Drs. Horsfall and Jones also found that grasshoppers were intermediate hosts for the tapeworm *Raillietina numida*. Dr. Cram reported that the land snail *Subulina octona* was the intermediate host for the poultry tapeworm *Davainea proglottina* in Puerto Rico, and that the transmission of *Capillaria contorta*, a crop threadworm of chickens, was direct and did not require an intermediate host.

The year 1937 was a very active period in avian parasitological research. Miss Cuvillier's doctor's thesis on the intestinal roundworm of domestic pigeons, *O. quadriradiatus*, which described its life history and pathogenicity, was published. Dr. Wehr found that turkeys of all ages were affected by gapeworms, that the pigeon becomes infected with the intestinal capillarid *Capillaria columbae* by ingesting the eggs of the parasite, and that chickens and turkeys become infected with *Capillaria annulata* by eating the earthworm intermediate hosts which had become infected by eating the eggs of the parasite. Drs. Horsfall and Jones published a detailed study of the life history of the poultry tapeworm *Choanotaenia infundabulum*, which requires dung beetles and grasshoppers as intermediate hosts, and added two common species of flour beetles to the list of intermediate hosts of the tapeworm. These flour beetles were also intermediate hosts of the tapeworms *Hymenolepis carioca* and *R. cesticillus*.

In 1938, Dr. Horsfall found that the poultry tapeworm *R. cesticillus* reduced weight gains in experimentally infected chickens and that the stunting continued through sexual maturity in the birds kept under observation for 21 weeks. Also, Dr. Wehr found that turkeys retained their tapeworm infections from one season to another and were easily reinfected, that chickens did not retain their infections as long as turkeys, and that guinea fowl were susceptible to tapeworm infection but did not develop typical symptoms of the disease. Dr. Wehr also reported that he was unable to infect pigeons and ducks with tapeworms.

Dr. Horsfall continued her research into 1939 and demonstrated that the larvae of meal beetles were susceptible to infection with the cysticercoids of the poultry tapeworm *R. cesticillus*. When pupae and adults of insects of the family Tenebrionidae harboring these cysticercoids were fed to chickens, they developed the adult tapeworm. *R. cesticillus* did not confer any immunity to the host, which apparently explains the heavy infections with this tapeworm frequently encountered in chickens kept under natural conditions.

Everett Lund reported in 1956 that the eggs of the cecal worm, *Heterakis gallinarum*, remained infectious to chicks and turkeys after 66 weeks in and on soil at Beltsville.

Protozoan Parasites—Histomoniasis: Dr. Theobald Smith in 1893 was investigating "blackhead disease" in turkeys, but it was not until 1928 that research on the protozoan parasites of poultry was reestablished in the Zoological Division.

In 1931, Dr. Ena A. Allen found a way to grow *Histomonas meleagridis*, the possible causative agent of blackhead in turkeys, in artificial media for the first time.

In 1946, Dr. Wehr and Miss Marion M. Farr demonstrated that eggs of the cecal worm, *Heterakis gallinarum*, which had been removed by anthelmintics, could still hatch and release the protozoan parasite *H. meleagridis*, which causes blackhead disease in poultry.

In 1961, Dr. Lund proved that the earthworm was a vector of the blackhead organism, *H. meleagridis*, and in 1965 he demonstrated that *H. meleagridis* grown in test tubes for five years would protect turkeys against experimental exposure to the blackhead organism given by rectal inoculation of fresh parasites. However, this procedure was not effective when vectora (earthworms) or eggs of the poultry cecal worm containing the blackhead organism were fed to the turkeys.

Coccidiosis: Dr. Ena A. Allen demonstrated in 1929 that resistance to infection with the coccidian *Eimeria tenella*, which produced the most virulent form of coccidiosis, was increased in chickens by a suitable ration, and in 1931 she reported that vitamins A and B in quantity lowered the mortality of chickens infected with *E. tenella*. In 1932, Dr. Allen published a paper on the influence of diet on the development of coccidiosis in chickens kept under sanitary conditions; she described two new species of coccidiosis in chickens kept under sanitary conditions and two new species of coccidia from grouse, *Eimeria angusta* and *E. bonasae*. In 1934, she published a key to the species of *Eimeria* in birds and four years later demonstrated that poultry coccidiosis could be successfully treated when chicks were given water containing traces of iron sulphate and copper sulphate. She noted that the "tonic" worked better when the chicks were treated before exposure to infection.

Dr. Schwartz reported in 1939 that investigations of poultry coccidiosis had shown the spindle-shaped infecting bodies (sporozoites) of *Eimeria acervulina*, originally contained in the oocysts, had excysted (hatched) and were free in the lumen of the duodenum 1-½ hours after the chicks had ingested them, and that they were in the epithelial cells lining the intestine within 54 hours of ingestion. Sixteen hours later, evidence of their multiplication was present, and 3 days after infection, the new generation of organisms had penetrated other epithelial cells. This developmental history was essentially the same as that of *Eimeria tenella*.

Dr. Allen in 1943 showed that repeated small doses of the cecal coccidium *Eimeria tenella* produced immunity to subsequent exposure for at least 6 months.

Dr. Wehr demonstrated in 1949 that certain species of coccidial oocysts from poultry could survive on soil for as long as 86 weeks in the vicinity of Beltsville, MD.

Dr. Wehr and Miss Farr in 1959 recormended prevention of coccidial infection in poultry by instituting strict sanitary measures and avoiding overcrowding of the birds. If infection does occur, they recommended the use of nitrofurazone and sulfaquinoxaline, nicarbazine, and nitrophenide for its control. If the disease becomes a serious problem and deaths begin to occur, the drug of choice is sulfaquinoxaline or sulfamethazine. The medicated water or mash must be prepared exactly as directed on the package or bottle containing the drug.

In 1961, Dr. McLoughlin and John L. Gardner found that *Eimeria tenella* could become drug resistant. Eight years later, Dr. McLoughlin and M.B. Chute demonstrated experimentally that drug resistance among the protozoa may in some cases be reversible. They demonstrated experimentally that an amprolium-resistant strain of *E. tenella* lost its resistance to the drug by exposure to acriflavine, fed in mash to chickens harboring the parasite. After six passages in the presence of acriflavine, the response of the amprolium-resistant strain to amprolium was approximately the same as that of an amprolium sensitive control strain. In 1969, these scientists showed that prior development of resistance to amprolium had no effect on the development of tolerance to the drug on second exposure as compared to sensitive strains that had not been previously exposed.

In 1979, Dr. Ruff and M. B. Chute showed that anticoccidial drugs given in the feed may be less efficacious if the feed is restricted. When potent anticoccidial drugs were administered in the feed without feed restriction, the medication often reduced the infection to a level insufficient to stimulate the development of a protective immunity. Conversely, when the same drugs were given in a restricted feeding regimen, they did not interfere with the development of immunity. These findings had an immediate application to the poultry industry. Of some importance were D. K. McLoughlin's observations that a restricted feeding program (i.e. a skip-a-day program) had no apparent effect on the

rate at which *E. tenella* developed resistance to amprolium or to clopidol.

David Doran, in 1962, developed a simple reliable *in vitro* method for obtaining large numbers of coccidial sporozoites, free from the oocyst wall that surrounded them. In 1967, Dr. Doran elucidated the complete life cycle of the poultry coccidium *Eimeria acervulina* and the next year found that coccidial sporozoites, freed from their cyst wall, could be frozen and stored indefinitely at -170°C without losing their viability.

John Vetterling in 1969 devised a method, utilizing continuous-flow differential density flotation, for recovery from chicken droppings large numbers of coccidial oocysts with a high percentage of sporulation. In the same year Dr. Doran scored a major advance toward the development of a protective vaccine against avian coccidiosis, by cultivating the highly pathogenic coccidium *Eimeria tenella* through its entire life cycle in primary cultures of chicken kidney cells. This was a major scientific achievement, which opened new areas of fundamental research in protozoology. For this achievement, Dr. Doran received the Superior Service Award from the U.S. Department of Agriculture. By 1979, Dr. Doran's method for the *in vitro* culture of *E. tenella* was being widely used throughout the world for drug screening and research work on protozoan parasite development and physiology.

In 1972, John M. Vetterling and P. A. Madden elucidated the ultrastructure of *Eimeria tenella* from sporozoite to first generation merozoite.

M. D. Ruff demonstrated in 1977 the synergistically-enhanced pathogenicity in chickens of concomittantly imposed infections of coccidioeis and aflatoxosis, and Dr. McLoughlin and M. B. Chute demonstrated in 1978, by serial propagation of *Eimeria tenella* in chickens fed a combination of commercial anticoccidials: amprolium, buquinolate, glycarbylamide and zoalene, each at one-fourth the usual field level, that this coccidium could develop resistance simultaneously to chemically unrelated compounds. Patricia Augustine also found that turkey coccidial sporozoites could be freed of the cyst wall surrounding them, in chickens as well as in turkeys.

In 1979, Dr. Doran demonstrated that *Eimeria meleagrimitis*, a highly pathogenic coccidian parasite of turkeys, could complete its life cycle in chickens given daily injections of a synthetic corticosteroid, dexamethazone, and produce oocysts that resulted in severe infections when fed to susceptible turkeys. He also found that *Eimeria maxima*, a parasite of chickens, had three asexual generations in its life cycle.

As part of the first investigation into the cause of death in chickens infected with *Eimera tenella*, Dale R. Witlock found that four major imbalances occurred: Hypothermia, exhausted energy reserves, acidosis, and renal failure. More than 30 variables were compared in 1980 in order to obtain a better understanding of the physiological changes associated with death from coccidiosis.

Dr. Ruff discovered in 1978 that the *in vitro* absorption of glucose and L-methionine in the intestine of broiler chickens was significantly reduced days after infection with sporulated oocysts of *Eimeria acervulina, E. mivati, E. maxima*, or *E. brunetti*, in the regions of maximum infection.

Compensatory absorption was observed in some uninfected regions where *E. acervulina* and *E. brunetti* were the infecting organisms, but not in the experiments with *E. mivati* and *E. maxima*.

Dr. Ruff reported in 1979 that marked changes in the body temperature, plasma glucose, liver glucose, liver glycogen, blood pH, and kidney tubular cell function occurred in birds dying from *E. tenella* infection, but did not occur in equally infected birds that survived the infection. This observation for the first time provided evidence that birds that die of coccidiosis have a different physiological response to the infection than those that survive it.

Hundreds of hybridoma-producing antibodies to various species of chicken coccidia were developed in 1981 by H. D. Danforth, using hybridoma-monoclonal antibody techniques.

In 1982, Dr. Ruff showed that exposing sporozoites of *E. tenella* to monoclonal antibodies directed specifically against this invasion stage dramatically inhibited the penetration of cultured primary chicken kidney cells by the sporozoites and the subsequent intracellular development of these parasites. The reduction with antibody treatment suggests that these antibodies may afford some protection against coccidial invasion. Efforts are currently underway to isolate the antigens recognized by the hybridoma antibodies to determine if these antigens will elicit a protective immune response in birds.

Trichonomoniasis—In 1930, Dr. Cram found a species of *Trichomonas* different from *T. gallinarum* of the chicken, causing a quail epizootic near Richmond, VA. Dr. Schwartz reported in 1939, that heating turkeys to a temperature of 104° to 106°F and maintaining a relative humidity of 90 percent in the specially built boxes in which they were confined, controlled trichomonad infections in the birds, although second and third treatments occasionally were necessary to get rid of the parasites completely. The treated birds gained weight and lost their trichomoniasis, whereas the untreated control birds lost weight and died.

Dogs, Cats, and Wild Carnivores

The parasites of dogs and cats, both internal and external, are important because these animals live in close proximity to man and are often infected with parasites that not only harm the animal, but some of which are transmissible to man. Those of wild carnivores are also important because they may be present in edible portions of game animals and if present may constitute a threat to human health unless rendered innocuous by heat or exposure to freezing temperatures.

The first dog parasite reported by a member of the staff of the Zoological Laboratory was a new coccidian, *Coccidium bigeminum* (Stiles, 1891). In 1894, Dr. Stiles first reported *Distoma westermani* (*Paragonimus westermani*), the oriental lung fluke, from a cat in the United States, and Stiles and Hassal reported another fluke, *Distoma* (*Dicrocoeliun*) *complexum*, also from a cat.

Dr. Maurice C. Hall described a new tapeworm, *Taenia balaniceps* (Hall, 1910) from a dog in the United States and placed the gid tapeworm in the genus *Multiceps*. Dr. Hall was also instrumental in having a Federal quarantine imposed on all imported sheep dogs to prevent the introduction of dangerous worms.

In 1914, Dr. Hall reported a new nematode parasite, *Rictularia splendida*, from the coyote. In 1915 he received his Ph.D. degree from George Washington University, Washington, DC, and published a paper on the dog as a carrier of parasites and disease in 1916, described a new tapeworm from a dog, *Multiceps gaigeri* (Hall, 1916) that had its larval stage in the goat, and in 1919 published a monograph on the taenoid cestodes of dogs, cats, and allied carnivores. In 1922, Dr. Hall reported for the first time in the United States, the intestinal fluke *Alaria americana* from the cat, described the internal parasites of foxes and treatments for removing them, described the eggs and larvae of the parasite of dogs, cats and foxes, and reported that the pin-worm *Oxyuris compar* of the cat was actually *O. ambigua* of the rabbit.

Dr. Hall, in 1923, reported on the diagnosis and treatment of the diseases caused by internal parasites of dogs, cats, and foxes, and discussed the relationship of the life histories of the parasites to the treatment given to remove them. Drs. Cram and Shillinger also reported the first successful experimental intro-uterine infection of pups with dog ascarids.

Dr. E. A. Chapin found in 1926 that the fluke causing salmon poisoning in dogs belonged in the family Heterophyidae and described it as a new genus and species, *Nanophyes* (*Nanophyetes*) *salmincola*. Wild carnivores were also found to be hosts of this parasite.

Larval tapeworms of the genus *Tetrathyridium* from a mongoose (*Herpestes* sp.) were reared to fertile maturity in dogs and cats in 1927 and found to belong to the genus *Mesocestoides*, a group of tapeworms of which the life histories were previously unknown, and which are important as parasites of dogs and cats.

The cat lungworm *Aeleurostrongylus abstrusus* was found for the first time in cats in the United States in 1930. Life history studies confirmed the findings of a British investigator that a cat became infected by eating mice infected with larvae of the lungworm. Also, Dr. Wright published the results of a study of the internal parasites of dogs in Washington, DC, and Mary Scott Skinker began a study of the tapeworms of North American carnivores as a part of a monograph on the tapeworms of the carnivores of the world. Miss Skinker's work resulted in the cataloguing of 20 genera, 90 named species, many unidentified species, and a number of species of uncertain position in the classification scheme.

Dr. Schwartz in 1932 reported on some cat and dog parasites that were transmissible to human beings and other domesticated animals. Dr. Wright published a paper on the heartworm of dogs, *Dirofilaria immitis* in 1933. This parasite had become a debilitating infection of hunting dogs and little was known about the parasite or treatment for its removal from affected dogs. Drs. Underwood and Paul D. Harwood found in 1937 that dogs could serve as reservoir hosts of the heartworm for 2-½ years after the reproductive activity of the adult worms had ceased. Fleas were found not

to be implicated in the transmission of heartworms in dogs.

Before resigning from the Zoological Division in June 1935, Miss Skinker described two new species of tapeworms from carnivores and published a redescription of *Taenia laticollis* (Rudolphi, 1819) from the lynx. She became a brilliant teacher at the Pennsylvania College for Women, and her required biology course so fascinated a student by the name of Rachel Louise Carson that Miss Carson almost abandoned her dream of a literary career. Later she became the famous author of "Silent Spring" and other nature books.

Dr. W. H. Wright published a paper in 1935 on the treatment of dogs and cats infected with internal parasites and Dr. Dikmans reviewed cases of canine babesiosis in the United States.

During her visit to Puerto Rico in 1936, Dr. Cram found that dogs and cats of the city of Mayaguez, PR, were heavily infected with ascarids, hookworms, three species of tapeworms—the fish tapeworm *Diphyllobothrium mansoni, Dipylidium* sp. and *Taenia* sp., acanthocephalids, and whipworms. The cats were infected with liver flukes, *Platynosomum concinnum*, capillarids in the urinary bladder, *Physoloptera* sp. in the stomach, and lungworms.

The Zoological Division and its successor the Beltsville Parasitological Laboratory, during the period 1941 to 1969, provided information to the U.S. Armed Forces on dog parasites in the Far East during World War II and the Korean and Vietnam conflicts. These parasites, particularly the dog heartworm, *Dirofilaria immitis*, were serious problems among sentry dogs in these areas.

Parasites of Rodents

Early stages of rabbit tapeworms were described in 1888 by personnel of the Zoological Laboratory. Dr. Stiles described a new fluke, *Distoma tricolor* (Stiles and Hassall, 1894). In 1895 six new tapeworms from these hosts were described and in 1896 a paper on the adult tapeworms of hares and rabbits was published. In 1928 Drs. Schwartz and Shook described the parasites and parasitic diseases of rabbits, and in 1932 Joseph E. Alicata reported on the life history of the rabbit stomach worm, *Obeliscoides cuniculi*.

Dr. Hall's Ph.D. thesis entitled "Nematode Parasites of Mammals of the Orders, Rodentia, Lagomorpha and Hyrocoides," was published in 1916. In 1924 Dr. Schwartz reported the protozoan *Eimeria falciformis*, from a white rat, for the first time in the United States and in 1935 Dr. Dikmans completed his extensive study of the nematode parasites of rodents and published a paper on new nematodes of the genus *Longistriata* in rodents.

Man

Hookworm Disease—Dr. Stiles published a report on hookworm disease in man and animals in the United States in 1901. He then made in 1902 what was probably his most important contribution to parasite research in the BAI: His discovery of the prevalence of human hookworm disease in certain sections of the Southern United States and the discovery during the same year of a new species of human hookworm, *Necator americanus*. It was first named *Uncinaria americana* but later was transferred to the new genus *Necator. N. americanus* is now known in other parts of the world and the other common species of human hookworm, *Ancylstoma duodenale*, known in Europe since 1843, is not rare in the United States. Dr. Stiles demonstrated that hookworms, which had been practically overlooked in this country, affected a high percentage of the rural population in many parts of the South, and that these parasites were responsible for much of the illness of the people of these localities, often wrongly described as laziness, shiftlessness, etc.

Since the remarkable findings of Dr. Stiles, great improvements in health conditions in rural communities in the South have been brought about through a campaign for hookworm eradication by counties and States. A worldwide campaign for hookworm eradication by the International Health Board of the Rockefeller Foundation also stemmed more or less directly from the hookworm investigations of Dr. Stiles (see section on anthelmintics for treatment development).

While engaged in intensive campaigns for hookworm eradication in the South in which attempts were made to change the "dog and cat" sanitation practices of the natives to using a privy or outhouse, Dr. Stiles was often referred to as Herr Geheimrat (Mr. Privy Councillor).

Other work on the hookworm diseases of man include the following:

1915 - Dr. Ransom reported the third American case in man of infection with *Diplydium caninum*, an adult tapeworm of the dog.

1921 - A new record was published noting the finding of the tapeworm *Hymenolepsis diminuta* in man.

1922 - Dr. Ransom reported on the effects of ascaris fluids of the large intestinal roundworm of man, *Ascaris lumbricoides*, on its host.

1923 - Dr. Ransom identified a new Golgylonema from man, possibly *G. hominis* (Stiles, 1921) a roundworm parasite of the esophagous.

1935 - Dr. Hall published a paper dealing with the relationship of parasitology to public health.

1961 - Joseph E. Alicata provided the first identification of the rat lungworm, *Angiostrongylus cantonensis*, from the brain of man, which led to the discovery that the nematode was the causative agent of parasitic or eosinophilic meningo-encephalitis. Also, Maybelle Chitwood, G. C. Velasquez, and N. G. Salazar identified and described a new nematode parasite of man, *Capillaria philippinensis*, that had caused more than 200 deaths in the Philippine Islands. (The accurate morphological observations and descriptions provided valuable clues to the life cycle of the parasite.) Human infection probably occurs from eating infective fish.

Protozoan Parasites—*Lamblia* (*Giardia*) *duodenalis*, a protozoan parasite of the intestinal tract, was reported from man for the first time in the United States in 1902.

In 1978, David Stiller and colleagues found that *Babesia microti*, a tick-borne pathogenic protozoan parasite of rodents and man, was readily transmitted orally to rodents, including a natural host species, the eastern whitefooted mouse, *Peromyscus leucopus*. This finding demonstrated for the first time the oral transmission of a haemoparasite. It also indicated that investigators working with this parasite should be aware of the possibility of oral infection. Dr. Stiller and colleagues reported in 1980 that a natural vector of this *Babesia*, which causes babesiosis in man, previously thought not to occur south of New Jersey, had been identified on Assateague Island, MD, in the absence of *B. microti*.

Miscellaneous Hosts

Dr. Stiles reported the occurrence of a protozoan parasite *Ichthyothirius multifilis* in fish in the United States in 1894 and also reported measures for its control in aquaria.

A survey of parasites of animals in North America, heretofore carried on in a casual way because of the lack of adequate personnel, was undertaken as a special detail in 1927, with a view to ascertaining rather definitely the distribution and importance of various parasites as a basis for selection of the most important problems in the field of parasitology in the United States.

Dr. Hall discussed arthropods as intermediate hosts of helminths in a paper published in 1929.

In 1930, an investigation of fish parasites in Oregon was carried out in cooperation with Oregon Agricultural Experiment Station.

In 1931, Benjamin G. Chitwood published a historical study of nematodes and in 1932 authored a synopsis of the nematodes parasitic in insects of the family Blattidae. Also in 1932, E. W. Price published a paper on the anatomy of nematodes and the value of using esophageal and cephalic structures for their classification.

In 1935, Dr. Wright published a paper on the prevention and treatment of parasites of large domestic animals.

BAI work in Puerto Rico yielded results. In 1936 Dr. Cram reported that the farm livestock on the island had fewer parasitic infections than livestock in the continental United States. Then in 1937, L. A. Spindler reported on his investigations of the effects of rain and sunlight on development of eggs and larvae of economically important nematode parasites of domestic animals under the tropical conditions encountered in Puerto Rico—investigations in cooperation with the Office of Experiment Stations, USDA. Dr. Spindler found that the combined factors of sunlight, heat, and airdrying in the tropics during the dry season probably were effective in destroying most parasitic eggs and larvae

on pasture, provided the growth of grass was not so dense as to protect the eggs and larvae from these inimical factors.

BAI scientists also contributed a number of other advances in 1937:

E. W. Price published his first paper on North American monogenic trematodes, I, The Superfamily Gyrodactyloides.

Studies on miscellaneous parasites produced descriptions of 4 new genera and 11 new species of trematodes.

Reported for the first time as a parasite of the chicken was the fluke *Clinostomum attenuatum*, normally parasitic in the American bittern.

Rana pipiens, the common frog, was found to be the second intermediate host of *Euryhelmis squamula*, a fluke parasite of minks and occasionally of cats.

During the year, 4 new genera and 20 new species of nematodes were described.

Sphaerocrystalloids of several economically important nematodes were studied from the chemico-physical standpoint and were found to be composed of calcium sulphate. They appeared to be related to the blood-sucking activity of *Ascaris, Strongylus*, and *Trichurus*.

Dr. Schwartz published a paper on the worm parasites of domestic animals.

Beginning in 1942, the staff of the Index-Catalogue of Medical and Veterinary Zoology compiled information for the Armed Forces during World War II, on the distribution and vectors of tropical parasitic diseases, such as malaria, filariasis and schistosomiasis, in strategic areas.

The Zoological Division cooperated with the War Food Administration, the Food and Drug Administration, and other Federal and nonfederal agencies, in 1944, to make available to the farmers adequate supplies of medicine for treating animals and safeguarding farmers against inferior or useless medications. The division in 1945 and later (1964) published "A Revised Check List of Internal and External Parasites of Domestic Animals in the United States, its Possessions, and Canada," including data on distribution. This work has been one of the most widely used and cited references in veterinary parasitology.

Aaron Goldberg in 1959 defined the role of good nutrition as an essential factor in protecting livestock, particularly cattle, against the effects of parasitic disease.

John C. Lotze and Robert G. Leek developed a successful procedure in 1965 for producing parasite-free and pathogen-free lambs. This achievement made possible experiments of types that heretofore could not be undertaken and provided a basis for the development of measures for the biological control of parasites.

Dr. Douvres developed methods in 1960 for growing worm parasites of livestock in artificial culture systems, a significant contribution to studies of physiological and immunological aspects of parasitism. By 1965, Dr. Douvres had also made notable progress toward the "deparasitization" of parasites. Eight species of nematodes had been grown *in vitro* through one or all of their parasitic stages and selected populations had been maintained over extended periods. Successful cultivation of "animal-free" generations of parasitic nematodes will not only rank as a major biological accomplishment in itself, but more importantly, will open a whole new vista in the basic research of parasitological phenomena and in the enormous potentialities of nonchemical or biological control of injurious parasites.

Dr. Douvres, in 1966, for the first time used mammalian tissue cultures successfully for the *in vitro* cultivation of a parasitic nematode and in 1980 developed new methods of cultivating gastro-intestinal nematodes of cattle that made it possible to obtain large numbers of advanced stages for use in investigating potential anti-parasitic drugs *in vitro* and collecting worm metabolic product for potential use as immunizing agents that are completely free of host contaminants and that have not been exposed to the host.

Dr. Frank Stringfellow developed a simple bioassay procedure in 1976 to detect pheromones in parasitic nematodes and in 1979 Dr. K. D. Murrell discovered that the protective immunity against *Strongyloides ratti* in the normal host was mediated primarily by humoral antibodies rather than cells.

EXTERNAL PARASITES

Ox Warbles

In 1890, Dr. Curtice's study of ox warbles was published. At first these parasites were thought to be the larvae of the heel fly *Hypoderma bovis* but in 1891 they were recognized as belonging to the other species of heel fly, *H. lineatum*. These investigations materially modified the former conceptions of the life history of these parasites. It had previously been supposed that the young larvae that hatched from the eggs deposited on the hairs of cattle by the warble flies burrowed into the skin of the back and there developed into the large grubs that formed the swellings on the backs of cattle known as warbles. These grubs leave the cattle when fully grown and after passing through a quiescent stage in the ground, the pupa, finally emerge as adult flies ready for reproduction. Dr. Curtice thought that the newly hatched fly larvae were licked off the skin by the host and swallowed to gain entrance into the host's body. Later, it was found that the newly hatched larvae actually burrow into the skin at the base of the hairs that bear the eggs from which they have hatched, and need not be swallowed to reach the esophagus, as Dr. Curtice assumed, but get there, apparently, by an active migration through the connective tissues from the point at which they penetrated the skin, later migrating from the esophagus up to the back.

In 1921, Marion Imes of the Zoological Division, BAI, and F. L. Schneider of the New Mexico Sheep Board found that wading tanks containing insecticidal fly-repellent solutions may prove helpful in reducing warble infestation among cattle that cannot readily be subjected to the handling necessary to administer other treatments that have thus far been found efficacious.

Dr. Ransom, in 1923 published a paper on ox warbles and grubby hides. Then in 1928, Dr. Marion Imes was assigned to work with the Bureau of Entomology on a cooperative project designed to develop methods for controlling *Hypoderma lineata*. In 1929, an extensive investigation of ox-warble control was undertaken with the Bureau of Entomology in Knox County, IL, and Prowers County, CO. The data showed only that light-colored animals were more grossly infested than dark-colored animals and that age was not as important a factor as was generally believed. In 1930, cooperative field investigations of cattle grub control were continued. The area in Prowers County used for this study was enlarged from 150 to 260 square miles, and that in Knox County was enlarged by the addition of one township. The removal of the grubs from the backs of cattle with forceps was found to be more economical than using a vaccuum apparatus. Rotenone was shown to be highly effective in killing the grub when brought into direct contact with it, and daily application of oils to the hairy coat of cattle, except the face, greatly reduced the grub infestation but did not prevent it.

Dr. Imes reported in 1938 that derris wash was superior to rotenone wash for the control of ox warbles, and that the application of either wash with a bristle brush was more effective than with a soft cloth. Moderate infestations with ox warbles were found to have no effect on milk production. In 1939, Dr. Imes found in Colorado that ox warbles interfered with the development of beef cattle and that washes with derris powder in water with soap added to make the chemical stick to the hair, applied every 3 to 4 weeks, as long as live warbles continued to appear in the backs of the cattle, might free the cattle from the parasite. Dr. Imes in 1944 found that rotenone-containing dusts were effective in destroying cattle grubs. By 1955, periodic treatment of cattle with a spray containing rotenone applied under high pressure killed the fly larvae in the backs of infected cattle and markedly reduced the warble fly population in the infested area.

Other External Parasites

Drs. Salmon and Stiles in 1898 compiled the existing knowledge of sheep scab (psoroptic mange) and the results of experiments conducted to discover a way to treat the disease. In 1901 they published a report on cattle ticks of the United States, described a pupa-like stage in the development of *Ornithodoros magnini* and reported *Boophilus australis* from Cuba and Puerto Rico.

On September 1, 1914, Dr. Marion Imes, a BAI veterinary inspector, transferred to the Zoological Division and was put in charge of the division's External Parasite Field Laboratory, recently established in Kansas City, KS. This had been done in response to a demand on the part of western ranchers for intensified USDA participation in the control of ectoparasitic diseases of livestock, particularly scabies of cattle and sheep. According to Dr. I. H. Roberts, director of the External Parasite Laboratory of the Animal Parasitology Institute (API), which is now closed, but had been located at Albuquerque, NM, Dr. Imes was an outstanding example of the devotion and dedication exhibited by many of the research scientists of the Zoological Division. He set up an office in the Federal Building in Kansas City, KS, with a single assistant who served as secretary, technician, and livestock man. He also bought a home with a few acres

adjoining where he kept a few cattle, sheep, and swine, bought with his own funds. The Zoological Division paid for feed, but for little else. For 14 years, Dr. Imes used his own animals to develop procedures for controlling lice, mites, and ticks affecting domestic livestock.

In 1916, Dr. Imes reported on his work with sheep scab and methods for its control and in 1917 he published a paper on the sheep tick *Melophagus ovinus* and methods for controlling it by dipping. In 1918 he reported on his studies of cattle lice, cattle scab, and the spinose ear tick, and methods for their control. Dr. Hall in 1922 described the construction of a vat for removing lice from cattle by dipping. Two years later, Dr. Imes reported that dipping or spraying of biting and sucking lice of horses with coal-tar creosote solutions or arsenical dips resulted in better control than any other methods used previously. Dr. Hall reported finding demodectic mange in a goat for the first time in the United States in 1924. Dr. Imes reported on lice, mange, and ticks of horses and methods of control and eradication in 1926 and the next year he found that sheep scabies and sheep and goat lice were spread by direct contact with infested animals.

In 1937, Dr. Imes described methods for the control and eradication of hog lice and hog mange and in the following year he discovered that a 3-percent lysol solution was an effective treatment for the removal of grubs from sheep suffering from grub-in-the-head infection by larvae of the fly *Oestrus ovis*. The treatment was more effective if saponated and forced into the nasal passages from tanks in which air pressure was maintained at 35 to 45 pounds per square inch, and the sheep were treated in a standing position. Dr. Imes reported in 1938 that specially prepared finely divided sulphur applied to sheep as a dip controlled the sheep tick but did not control lice. The sulphur remained on the wool for several months and acted as a repellent to sheep ticks. Dr. Imes found in 1939 that a single dipping with fused bentonite-sulfur solution eradicated sheep ticks. But in 1944, he reported that fixed nicotine dips were of limited value against this parasite.

Allen McIntosh of the Parasite Classification and Distribution Unit of the Beltsville Parasitological Laboratory provided prompt identification of the African red tick, *Rhipicephalus evertsi*, an exotic species which was found for the first time in the United States in 1960. This information facilitated the eradication of this parasite, a known vector of several important diseases of livestock.

TREATMENT

Anthelmintics

For centuries the drugs known as anthelmintics had been a heterogenous group of "worm medicines" concerning which there was little definite knowledge. Effective and ineffective drugs were recommended alike on the basis of clinical experience only.

As early as 1896, BAI investigators began reporting on the safety and efficacy of these treatments. In that year C. W. Stiles published the results of experiments on the tolerance of chickens for copper sulfate solutions and for turpentine. In 1901 he reported on treatments for roundworm in cattle, sheep, and goats. Results of experiments published in 1902 indicated that arsenic, thymol, and creosote were of no value in expelling the fringed tapeworm of sheep that intertrachael injections, fumigations, and oral administration of substances eliminated through the lungs were of no value in killing lungworms, and that copper sulfate, gasoline, thymol, and creosote were of some value in controlling stomach worms and other nematodes of ruminants.

Dr. Stiles also reported that when sheep are dosed in the standing position, the liquids administered go directly to the fourth stomach, for the most part. This conclusion was based on the experimental administration of colored fluids, the treated animal being killed and immediately examined postmortem. The efficacy of the anthelmintics that were tested was judged in part from fecal examinations after treatment, in part from postmortem examinations, and in part from clinical improvement of treated animals. Also in 1902, Stiles and Pfender reported the results of experiments to determine the efficacy of thymol in removing whipworms from dogs. In these experiments, feces were examined after treatment and the animals were subsequently examined postmortem.

In 1912, Drs. Ransom and Hall carried out some experiments on the effect of anthelmintics on parasites situated outside the lumen of the digestive tract. They treated sheep with carbon bisulphide, male fern, and a proprietary remedy consisting of 49 percent ferrous sulphate, 12 percent arsenous oxide, 8 percent oxides of calcium, potassium, silicon, and magnesium, and 29 percent organic matter (nature not determined but not containing santonin or any other

vegetable alkaloid) as remedies for *Thysonoma actinoides* (liver tapeworm) infection. Their results were negative, but they felt that further experimentation along this line should be done.

The subject of anthelmintic treatment was made a separate project of the Division in 1915, and experiments were begun by Dr. Hall and Winthrop Foster. The method adopted for testing drugs consisted of administration of definite doses of drugs to animals, carefully collecting all parasites from the feces passed up to the time the animal was killed, usually a period of 4 days, and then collecting all worms present postmortem. In this way the efficacy of a drug could be ascertained accurately for doses used and under conditions of the experiment.

As a result of critical tests of this sort, numerous anthelmintics recommended on the basis of clinical experience for removal of worms from various host animals have been found ineffective and unreliable while other anthelmintics recommended on the same basis have been found as effective as clinical experience had indicated. In some cases the therapeutic dose definitely has been ascertained for these drugs for the first time and in other cases the proper technique and procedure in administering the drug have been ascertained.

Largely as a result of these studies and others similar to them, a number of dependable treatments, established by critical tests, have been developed for many of the parasitic diseases. Since 1923 we can say that we have many dependable treatments, based on exact information, for most of the parasitic worms of domestic animals, and an established experimental method of proved value for finding such treatments for other worms.

In 1918, Drs. Hall and Foster published a comprehensive study on the use of anthelmintics, including the effectiveness of oil of chenopodium for removing ascarids from dogs and swine. Dr. Hall in 1919 reported on the use of monthly treatments with copper sulfate solution combined with pasture rotation as a control measure for stomach worms of sheep.

In further investigations, substances not then used as anthelmintics were tested to determine their possible use for removal of worm parasites. In 1921, Dr. Hall reported that one such substance, carbon tetrachloride, when used as an anthelmintic, was more effective in removing hookworms from dogs than other remedies then in use. It was also quite effective in removing ascarids from dogs and was much used for treating dogs and foxes owing to its being distinctly safer than the somewhat more effective oil of chenopodium. It also had the advantage of being a definite chemical and not a variable mixture like oil of chenopodium was. Furthermore, bad effects suffered by some animals after being given the chemical were found to be lessened or avoided by simultaneous administration of Epsom salt. Carbon tetrachloride was recommended in correspondence with veterinarians for trial as a drug for removing hookworms from fur foxes. It soon became established in veterinary medicine as the best treatment then available for removing hookworms from dogs and foxes. It was also shown to be effective in removing intestinal roundworms (strongyles and ascarids) from horses.

On the basis of these facts, of toxicity tests on monkeys made in cooperation with the Hygienic Laboratory of the U. S. Public Health Service, and of the absence of unpleasant symptoms when the investigator, M. C. Hall, took the indicated therapeutic dose for man, the drug was brought to the attention of the medical profession. The Rockefeller Foundation promptly undertook the work of testing it in human medicine.

After carbon tetrachloride had been used successfully to treat more than 15 million persons for removal of hookworms, Dr. Hall's discovery of the anthelmintic properties of the hydrocarbon was evaluated by S. M. Lambert, field director of the International Health Board of the Rockefeller Foundation. "Dr. Hall's introduction of the carbon tetrachloride treatment has made the mass treatment of populations for hookworm feasible . . . I reckon this as the greatest contribution to tropical medicine after the work of Ross on malaria and the work of Reed *et al* and Gorgas on yellow fever."

Dr. Hall, in 1922, reported further on the action of carbon tetrachloride against parasites within the lumen of the digestive tract as well as against those outside of it in the tissues of the treated animals. In 1923, Dr. Hall reported on the use of arecolin hydrobromide as an anthelmintic and on the successful removal of cecal worms from poultry by rectal injections of anthelmintics, besides additional observations on the anthelmintic action of carbon tetrachloride. Dr. Hall, alone or in collaboration with J. E. Shillinger of the Bureau of Biological Survey, published 20 papers on anthelmintics in 1923. Five of these papers also dealt with diagnostic procedures for determining the identity of parasites before treatment. The relation of the life histories of the parasites to the type of treatment given to remove them was also discussed. E. M. Nighbert in Schuyler County, MO, and Dr. Cooper Curtice near Vienna, VA, both reported that treatment of sheep on pasture with a one-percent solution of copper sulphate at 1-month intervals gave excellent control of roundworm parasites.

Experiments with chlorine compounds in 1924 suggested that their anthelmintic efficacy might be correlated with their composition and solubility. Dr. Hall reviewed the developments in veterinary parasitology during the preceding 15 years and emphasized the great improvement in our understanding of anthelmintics and their uses, and of the life histories of parasites, the pathological effects of parasitic infection, and the prophylactic measures that could be taken against them.

In 1925, tetrachlorethylene was added to the list of clorinated hydrocarbons for the removal of hookworns and other intestinal roundworms, and in 1927 it was found to be superior in some instances to carbon tetrachloride in human medicine. Dr. Curtice, in 1927, reported that under heavy stocking conditions at McNeill, MS, sheep had to be dosed with a solution of copper sulphate every 2 weeks to control gastrointestinal worms, instead of every 3 weeks as had been satisfactory in Vienna, VA.

Carbon tetrachloride was reported in 1928 to be effective in removing *Capillaria columbae*, an intestinal hairworm of chickens, and tetrachlorethylene passed satisfactory laboratory tests as a good anthelmintic. Dr. Hall published an article on the theoretical and practical consideration of anthelmintics and his "Calendar of Livestock Parasites" was made available to the public.

Investigations in collaboration with the Biochemic Division disclosed in 1929 that the anthelmintic efficacy of about 20 halogenated hydrocarbons varied with the number and position of the chlorine atoms in the molecule, and that marked anthelmintic action may be obtained with mono-chlorinated hydrocarbons as well as with those more heavily chlorinated. These studies resulted in the discovery of new nontoxic anthelmintics. Also, tests with a 1 percent copper sulphate solution, tetrachlorethylene, and carbon tetrachloride, administered weekly to sheep, resulted in good control of the parasites, but the sheep given carbon tetrachloride died. Oil of chenopodium and tetrachlorethylene were found to be fairly effective in removing the pinworm *Passalurus ambiguus* from rabbits.

The Zoological Division in cooperation with the Biochemic Division found in 1930 that the decomposition of tetrachlorethylene on standing could be almost entirely prevented by adding phenol, toluene, or kerosene to the tetrachlorethylene in the proportion of 0.1 percent. Also by adding a 1-inch layer of water over the tetrachlorethylene, the poisonous decomposition product phosgene was removed and the comparative purity of the hydrocarbon was preserved. An investigation of the chlorinated alkyl hydrocarbons demonstrated that the anthelmintic activity of these compounds for hookworms was correlated with the number of chlorine atoms and their position in the molecule, and the compounds' solubility in water. The optimum solubility was between 1 part of the compound to 1,500 parts of water and 1 part in 2,000 parts of water. A series of experiments carried out with compounds formed between alkyl hydrocarbons and iodine and bromine showed that while such compounds possessed anthelmintic properties, they were not found to be of greater value than the chlorinated hydrocarbons.

Kamala, a reddish cathartic powder from the capsules of the East Indian tree *Mallotus philippinensis* that contains rottlarin, was used successfully in 1931 to remove tapeworms from the guinea fowl. Also in 1931, W. H. Wright, P. C. Underwood, and John Bozievich reported the results of critical tests of miscellaneous drugs as anthelmintics to remove ascarids, whipworms, and nodular worms from swine.

In 1932, Drs. Wright and Shaffer reported the results of critical tests of chlorinated alkyl hydrocarbons showing the correlation between their anthelmintic efficacy and their chemical structure and physical properties. The same year, Dr. Wright demonstrated that the chemical n-butyl-chloride was an effective anthelmintic against ascarids, hookworns, and whipworns in dogs.

Dr. Wright reported in 1933 that fouadin, an antimony compound, was useful for removing heartworms (*Dirofilaria immitis*) from dogs. Also in 1933, Drs. Wright, Underwood, and Jacob M. Schaffer, and Mr. John Bozievich announced the discovery of a new anthelmintic, n-butylidene chloride. Then in 1934, Dr. Wright reported on the therapeutic value of Stibophen, another antimony compound, for controlling heartworm infection in dogs. In 1935, Dr. Hall published a paper entitled "Therapeutics of Worm Diseases."

John T. Lucker of the Zoological Division and J. E. Shaffer of the Biochemic Division demonstrated in 1936 that the effectiveness of chlorinated hydrocarbons for killing ascarid eggs and larvae in horse manure was related to their volatility rather than to their water solubility.

Experiments with n-butyl-chloride in 1937 showed that with doses of 1 cc per kilogram of body weight, the drug

had an efficacy of 61 percent for removing whipworms and 100 percent against hookworms and ascarids in dogs. It also removed 99 to 100 percent of all cylicostomes and between 70 and 100 percent of all *Strongylus* spp. from two horses and was also effective against the pinworms *Oxyuris* sp. and *Probstmyaria vivipara*.

Fouadin was still the drug of choice in 1937 for killing the microfilariae in the blood and adult heartworms in the heart. None of 13 other compounds were efficacious against this parasite.

Tobacco dust in mash and p-tertiary amyl phenol given in formalized gelatin capsules were used succesfully for treating pigeons for the removal of large intestinal roundworms.

In 1938, exposure of unembryonated eggs of *Toxacara canis* to small quantities of ethylene dichloride or to a mixture of ethylene dichloride and carbon tetrachloride in closed containers for 46 to 94 hours prevented development of the eggs and apparently destroyed their viability. Infective eggs of *T. canis* were destroyed when exposed to the mixture for 90 hours in a closed container. Also in 1938, cooperative experiments with the Biochemic Division to develop an effective treatment for the removal of gapeworms from poultry resulted in the discovery of only one satisfactory chemical, barium antimonyl tartrate. It removed 98 percent of the gapeworms from chickens and, with an improved technique of administration, 85 percent of the gapeworms from turkeys.

Probably the most important contribution to parasitological knowledge made by personnel of the Zoological Division during the next 10 years was made in 1939 by Paul D. Harwood when he discovered the broad spectrum anthelmintic action of phenothiazine against worm parasites of livestock and poultry. Dr. Harwood demonstrated that phenothiazine was effective in removing the cecal worm *Heterakis gallinarum*, carrier of the causative agent of blackhead, *Histomonas meleagridis*, from poultry.

Drs. R. T. Habermann and Harwood developed a concentrated (recrystallized) phenothiazine in 1939, that enabled the therapeutic dose for sheep to be decreased from .5 gram per pound of body weight to .2 to .25 gram per pound of body weight. This change made possible the giving of drug capsules, whereas the more bulky commercial product could not be administered in this manner. The BAI applied for a public-service patent for phenothiazine so the preparation and distribution of the compound would be open to all interested manufacturers. Commercial production of the chemical in a form suitable for use as an anthelmintic was begun.

In 1940, Drs. Harwood, Habermann, I. H. Roberts, and Mr. W. H. Hunt found that phenothiazine showed promise of controlling intestinal roundworms of horses. In 1942, Drs. Harwood and Habermann discovered, developed, and standardized the use of free-choice low-level phenothiazine-mineral mixtures for reducing pasture contamination with the infective stages of gastrointestinal nematode parasites affecting sheep, cattle, horses, and other livestock.

Dr. Everett E. Wehr reported an efficacy of 92 to 95 percent in the removal of gapeworms when treating infected chickens and turkey poults by forcing them to inhale barium antimonyl tartrate as a dust in a box in which 50 one-month old birds could be treated at one time. The Department of Agriculture also obtained a patent for the use of this chemical by the poultry industry of the United States.

Dr. L. A. Spindler demonstrated in 1943 that feeding skim milk to pigs was useful in controlling gastrointestinal helminth infections in swine.

In 1944, Dr. Harwood found that standard therapeutic doses of phenothiazine were safe for calves, that sheep thrived under continuous phenothiazine-salt treatment, and that parasites were well controlled in a herd of 126 goats with weekly saltings with a mixture of 7 parts of salt and one part phenothiazine (total 8 pounds) mixed with enough grain to make the mixture attractive to the animals. This quantity of medication provided one-half gram of phenothiazine per day per animal having access to the phenothiazine-salt mixture. At about this same time a hexachloroethane-bentonite suspension proved very effective for the control of liver flukes in cattle in Florida and Texas. 1944 was also the year Dr. Enzie reported that perthiocyanic acid was an effective drug for the removal of tapeworms from dogs in doses of 0.1 to 0.2 gram per pound of body weight and that para-tertiary-butyl-phenol, designated as "butylphen," in doses of 0.1 to 1.0 gram per pound of body weight, removed hookworms, ascardis, and whipworms.

Drs. Enzie and Harwood in 1945 developed and standardized the sodium fluoride treatment for the removal of large roundworms from swine.

Apparently from 1945 to 1960 very little of importance was accomplished in the development of new anthelmintics. However, in 1960 a project initiated by Merle Colglazier, and carried out by Mr. Colglazier and Drs. Whitmore, Kates, Turner, Foster, and Lindahl showed that ineffective control of gastrointestinal parasitism of sheep at Beltsville, despite frequent medication with the best available anthelmintics, was ascribable to infection with a phenothiazine-resistant strain of *Haemonchus contortus*, the large stomach worm and major pathogen of the flock.

In 1960, F. D. Enzie and Mr. Colglazier reported on the taeniacidal action of bithionol against tapeworm infections in dogs, cats, and sheep. Rex W. Allen, F. D. Enzie, and K. S. Samson found in 1962 that bithionol was quite effective against *Thysanosoma actinioides*, the liver tapeworm of sheep. This work was done at the ADP Division's field station at Las Cruces, NM.

Dr. Wehr and Mr. Colglazier demonstrated in 1965 that feeding to pigeons and turkeys mash containing 0.3 to 0.5 percent by weight of thiabendazole resulted in the removal of large intestinal roundworms, *Ascaridia columbae*, from the pigeons and gapeworms, *Syngamus trachea*, from the turkeys. Heretofore birds could be treated for gapeworms only by forcing them to inhale the dust of barium antimonyl tartrate. No adverse effects of the drug were observed.

The therapeutic value of niclosamide against the fringed tapeworm of sheep, *t. actinioides*, was reported in 1967 by Rex W. Allen, F. D. Enzie, and K. S. Samson.

Two years later Dr. Enzie and Mr. Colglazier found that two new drugs, levo-tetra-misole and parbendazole, showed superior efficacy against some species of parasites when compared with established drugs phenothiazine and thiabendazole. They were also more effective against the larval stages of the large stomach worm, *Haemonchus contortus*, and the intestinal thread-necked worm, *Nematodirus spathiger*, than the other two drugs. In the same year, 1969, Dr. Wehr and Mr. Colglazier demonstrated for the first time that a new anthelmintic, tetramisole, was highly effective against the large roundworm of poultry, *Ascaridia dissimilis*, the cecal worm, *Heterakis gallinarum*, and the intestinal threadworm, *Capillaria obsignata*, in turkeys. Tetramisole was the first effective anthelmintic found that would remove *C. obsignata*.

R. S. Rew found in 1979 that the drug diamfenetide was prophylactically effective in totally preventing infection of sheep with the liver fluke, *Fasciola hepatica*, when the drug was continuously infused into sheep at a dose rate of 5 to 7 mg per kilogram of body weight, which suggested that slow release preparations of this drug could provide a practical and efficient method of controlling liver fluke infection.

In 1980, F. W. Douvres found that synthetically produced chemicals, similar to insect growth hormone regulators, killed ruminant nematode parasites, and Dr. Rew and Mr. Colglazier showed that repeated low-level treatment of sheep with antiparasitic medication was more efficacious and less toxic than then-current treatments. They suggested that the development of time-released formulations of antiparasitics based on levels found effective by such testing could revolutionize management practices for cattle and sheep in the United States and perhaps throughout the world.

Drug Resistance

The development of resistance to the anthelmintic action of drugs by parasites repeatedly exposed to them under natural conditions has long been recognized. In 1969, Mr. Colglazier demonstrated for the first time in Maryland the development of resistance in a strain of the large stomach worm of sheep, *Haemonchus contortu*, to the widely used drug thiabendazole.

Dr. Enzie and Mr. Colglazier in 1971 demonstrated for the first time that sheep strains of the common stomach worm, *Haemonchus contortus*, resistant to widely used benzimidazole anthelmintics such as thiabendazole, were sueceptible to nonbenzimidazole compounds such as levamisole.

K. C. Kates and Mr. Colglazier in 1972 produced for the first time experimentally a cambendazole-resistant strain of the highly pathogenic stomach worm of sheep, *Haemonchus contortus*, demonstrating the marked potential for the rapid emergence of drug-resistant worm parasites in livestock. Three years later, R. D. Romanowski demonstrated that the basis for nematode resistance to anthelmintics of the benzimidazole class involved the parasite's ability to activate an essential metabolic enzyme.

It was not until 1979 that K. C. Kates, F. D. Enzie, and Merle Colglazier, all of the API staff, were able to produce

experimentally a drug-resistant strain of the ruminant stomach worm. They also found that the increase in drug resistance could be overcome, at least partially, by increasing the drug dose.

Immunization

In 1973, Drs. Herlich, Douvres, and Robert Romanowski demonstrated the potential for immunizing cattle against gastrointestinal helminth parasites by vaccination with larval stages of the parasites grown *in vitro*.

Dr. Herlich showed in 1977 that immunity to important stomach parasites of cattle developed very slowly, requiring 6 to 9 months chronic exposure to the parasites. The following year he reported that the daily inoculation of calves with 1,000 infective larvae of *Trichostrongylus axei*, a gastrointestinal nematode parasite of cattle, conferred little or no immunity to challenge inoculation at 10 and 21 weeks. Since calves are almost 100 percent resistant to challenge inoculation after 30 weeks, control of this parasite by immunization or vaccination may be economically impractical.

THE INDEX-CATALOGUE OF MEDICAL AND VETERINARY ZOOLOGY

Mildred A. Doss, head of the Index-Catalogue staff, stated in her 1953 paper "The Index-Catalogue of Medical and Veterinary Zoology," that the Index-Catalogue "is an index to the world's literature on parasites and parasitisms of man, of domestic animals, and of wild animals whose parasites may be transmitted to man and domestic animals. Included also are references to parasites of fur-bearing animals, wildlife, and to free-living and plant parasitic nematodes or roundworms, which are recognized as important in reducing yields and rendering otherwise valuable land virtually useless for raising certain types of food and forage crops."

The Index-Catalogue was started by the late Dr. Albert Hassall shortly after he became Dr. Stiles' assistant in 1891. One of his duties was to look up references to the parasitological literature for his chief. Since these references were, at that time, difficult to secure, he conceived the idea of saving the reference cards so they might be readily available for future use. With the passage of time, the accumulation of references was expanded first to meet the needs of the increased staff of the laboratory and then to meet the requirements of a growing and expanding science of parasitology.

Dr. Hassall was the recipient of the Steele Medal in 1922, awarded to him by the Royal College of Veterinary Surgeons of London, England, for "distinguished service to Veterinary Medicine," to honor him for his initiation of the Index-Catalogue, which had been of inestimable value to veterinary parasitologists. At the dinner held to celebrate the occasion, N. A. Cobb, Head of the Office of Nematology, Plant Industry Station, Beltsville, MD, read the following poem, which he had written:

"The Recording Angel"
(Postprandial)

When I met the recording angel
Of the mighty B.A.I.
My sins rise up before me
And smite me hip and thigh
For I know there's no escaping
His well known, eagle eye
He spots my every error
And intends to till I die
And he writes them in his Files.
Inscribes them in his Files.

If I have two MS species
Of the same generic form
And because I'm absent minded
Or my brain is in a storm,
I name them in terms identic
For my old friend Dr. Dorm,
it's "What the Hell you doing?"—
Or something just as "warm"
So this escapes his Files,
Thanks be, escapes his Files.

But if I rediscover
A form from the misty past
And mistakenly rename it,
I never hear the last
Of how I've bunged the works up
With the "wrenches" I have cast
"At your abysmal ignorance
The whole world stands aghast."
For he'll have it in his Files,
He'll have it in his Files.

If I named a species "minor"
In the long, long, long ago,
And after time's gone flying
What seems an age or so, —
I apply it to a brother species,
I quaff the bitterest woe:
It's Cobb, your case is hopeless,
I'd make my will and go:
He'll have it in his Files,
He'll have it in his Files.

And when I land in Tophet
I shall hear it relayed down
From the land I left behind me,
As I sizzle and I brown;—
"There's one thing I'd forgotten,
That genus from beyond the town,
The name you went and gave it
Is an adjective not a noun."
It's up there in his Files,
It's up there in his Files.

The Index-Catalogue was designed to serve the needs of a particular branch of science and its designers were scientists who worked in the field and understood its needs. Materials for the Index-Catalogue were derived from many sources. Certain periodicals were received on regular circulation from the Library of the Agriculture Department (later called the National Agricultural Library). Standard indices, such as the Bibliography of Agriculture, Current List of Medical Literature, Zoological Record, and Index-Veterinarius, were checked. From the 1920's or earlier, members of the Index-Catalogue staff have had work space and have done much searching and indexing of literature at the library of the Surgeon General of the United States, which eventually evolved into the National Library of Medicine. Abstract journals, including Biological Abstracts, Chemical Abstracts, Tropical Diseases Bulletin, Veterinary Bulletin, and the Review of Applied Entomology were searched, as were the bibliographies of articles indexed. Reprints and journals received by members of the Index-Catalogue staff and by friends working in the field were often available for indexing. Reports of experiment stations, departments of agriculture, foundations, councils, conventions, and expeditions also were indexed.

Unverified references from these sources were verified by going to the library likely to have the original or by requesting the original through inter-library loan. Visits were made for verification of references to the John Crerar Library in Chicago, to the New York City Public Library (which does not loan books), and to libraries in Copenhagen, Denmark; London and St. Albans, England; Paris, France; and Leningrad, USSR. References in 32 languages are included in the Index-Catalogue.

Also a second section of the Index-Catalogue was prepared by listing the hosts of the parasites alphabetically within their zoological groupings, and there listing the parasites reported for them. The first part of the BAI's Host-Catalogue was put together in 1924 in collaboration with the Hygienic Laboratory of the U.S. Public Health Service, "Key-Catalogue of the Protozoa Reported for Man" was published in 1925. It provided a much needed index to the literature in this important field of parasitology. Other valuable Key-Catalogues were published in subsequent years: worms reported for man, 1926; crustaceans and arachnoids of importance to public health, 1928; parasites reported for primates (monkeys and lemurs), with their possible public health importance, 1929; parasites reported for Chiroptera (bats), with their possible public health importance, and one on parasites reported for Insectivora (moles, shrews, hedgehogs, and related mammals), with their possible public health importance, 1932; and parasites reported for Carnivora (cats, dogs, bears, etc.), with their possible public health importance, 1935.

A systematic card catalogue of bird nematodes was compiled in 1927 as a separate section of the Index-Catalogue and a very comprehensive set of illustrations of bird nematodes was assembled by Dr. Cram. In 1930, a new section was added to cover systematically the invertebrate hosts of parasites of vertebrates.

Preparations were made in 1931 to begin publication of the author catalogue of the "Index-Catalogue of Medical and Veterinary Zoology," repeating the previous author catalogue with additions necessary to bring it up to date. Part I, Author Aall to Azzoline, the first volume of the new author catalogue by Albert Hassall, senior zoologist, and Margie Potter, junior librarian, was published in 1932. Part 2, Authors B. to Bychkov, by Albert Hassall, Collaborator, Margie Potter, Mildred A. Doss, and Marion M. Farr, junior librarians, and Gertrude B. Carson, library assistant, was published in 1938. Involvement of the United States in World War II brought about a suspension of publication of the Index-Catalogue from 1942 to 1946.

Miss Doss, head of the Index-Catalogue staff, and her co-workers completed publication of the 18-part author index of the Index-Catalogue in 1952. During the period 1952-1956, Supplements 1-6 to the author index were published, bringing it completely up to date. Complete author index supplements have been published annually since 1957, thus keeping it current.

Miss Doss received the Superior Service Award of the U.S. Department of Agriculture in 1954 for her accomplishment in completing the author index. Although Dr. Hassall had retired in 1932 and had passed away in 1942, he was listed as a collaborator by the compilers of the author index through 1952.

Miss Doss retired in 1961 in order to prepare unpublished trematode records in the Index-Catalogue files for publication.

Dorothy Segal, Miss Doss's successor, inaugurated a new format for the Index-Catalogue in 1965. Beginning with Supplement 15, the publication was divided into seven parts: (1) Authors; (2) Parasites: Protozoa; (3) Parasites: Trematode and Cestoda; (4) Parasites: Nematoda and Acanthocenhala; (5) Parasites: Arthropoda and Miscellaneous Phyla; (6) Subject Headings and Treatment (including anthelmintics and insecticides used to control arthropod parasites of animals); and (7) Hosts. The publication of these indices, which was not done previously, greatly increased the usefulness

of the Index-Catalogue by making available scientific information on new developments related to parasitology in such fields as biochemistry, pathology, immunology, physiology, cytology, genetics, tissue culture, ultramicroscopy, radiobiology, pharmacology, zoogeography, and the biological control of parasites. Every labor-saving and cost-saving technique for detecting, indexing, cataloguing, copying, and reproducing was drawn upon to keep abreast of the mushrooming parasitological literature.

The 12 parts of the Index-Catalogue dealing with the Trematoda and Trematode Diseases were published from 1963 to 1969. These publications included information on specific and subspecific names of the parasites, and on their hosts.

At the request of the U.S. Armed Forces, Mrs. Segal and the Index-Catalogue staff in 1969 compiled and published a special bibliography and list of parasites of man and domestic animals in Vietnam.

A series of special publications of the Index-Catalogue of Medical and Veterinary Zoology has also been published: Special Publication No. 1, Checklist of the Internal and External Parasites of Deer, *Odocoileus hemionus* and *O. virginianus*, in the United States and Canada, by M. L. Walker and W. W. Becklund (1970); "Special Publication No. 2, Bibliography on Chagas' Disease (1909-1969), by M. C. Olivier and L. J. Olivier, of the Pan-American Health Organization, and D. S. Segal (1972); Special Publication No. 3, Ticks and Tickborne Diseases, by M. A. Doss, M. M. Farr, K. F. Roach and G. Anastos, Professor of Zoology at the University of Maryland (1974-1978); Special Publication No. 4, Checklist of Types in the U. S. National Parasite Collection, by E. J. Salley, in collaboration with J. R. Lichtenfels and J. H. Shaw (1978); Special Publication No. 5, List of Translations, by Shirley J. Edwards, head of the Index-Catalogue staff, (1981); and Special Publication No. 6, Subject: Nematoda and Nematode Diseases, Part 1 (1981), Part 2 (1983), by M. A. Doss and D. T. Hanfman.

Supplement 24 (1982) of the Index-Catalogue was published and marketed by the Oryx Press, Phoenix, AZ. In 1982, the operation of the Index-Catalogue was computerized. This new system, designed for the Index-Catalogue, continues to provide in-depth indexing. The system can produce cards to maintain the cumulative card files, a computer tape for publication of the printed catalogues, and records for on-line searching. The Index-Catalogue of Medical and Veterinary Zoology has become a sub-file of AGRICOLA (AGRICulture On-Line Access), the cataloguing and indexing database of the National Agricultural Library, Beltsville, MD, 20705. The computerized database consists of approximately 18,000 indexed papers and grows daily. Supplement 25 has been completed and is now "on-line" in AGRICOLA. AGRICOLA is File 10 of the Lockheed DIALOG system. As of September 1984 there were more than five million cards in the reference files of the Index-Catalogue.

With the beginning of Fiscal Year 1985, ARS will turn over the indexing of parasitological literature to the National Agricultural Library. Indexing will continue, but will not be done in as much detail as previously, and the venerable and valuable Index-Catalogue of Medical and Veterinary Zoology will lose its identity.

BIOSYSTEMATICS LABORATORY

Dr. Hassall always maintained that a scientific name was "only a collection of letters and no other d—n thing," but the bestowing of scientific names on parasites and classifying them in accordance with the International Rules of Zoological Nomenclature continue to be of primary importance in the field of animal parasitology.

One of the early publications of the Zoological Laboratory was an inventory of genera and subgenera of the trematode family Fasciolidae, the group to which the common liver fluke belongs. This paper was published in 1898 by Stiles and Hassall. The next year they described the internal parasites of the fur seal, including a new hookworm, later named *Uncinaria lucasi*, which was causing deaths among the seals. In 1902, Dr. Stiles discovered a new species of human hookworm, which he named *Uncinaria americana*. This parasite was later transferred to the genus *Necator* on the basis of a more intimate knowledge of its anatomical structure. During the years that followed, several new parasites of domesticated animals in the United States were described and systematic studies of several genera were made and published by Drs. Ransom and Hall (see sections on specific parasites). E. A. Chapin reviewed the gapeworm genera, *Syngamus* von Siebold and *Cyathostoma* E. Blanchard, in 1925, and E. W. Price described new genera and species of the trematode family, Schistosomidae, in 1929.

In 1931, Mr. Lucker described a new genus and species of trematode worms of the family Plagiorchidae, and Dr. Sinitsin discussed the life histories of the trematodes *Plagioporus siliculus* and *P. virens*, with special reference to the origin of the Digenea trematodes requiring more than one host to complete their life cycle. Dr. Wehr in 1935 pub-

lished a revised classification of the superfamily Filaroidea. Routine identifications of parasites made during 1937 for various governmental agencies, education institutions and individuals included 320 nematodes and acanthocephalids, 104 cestodes, 52 trematodes, 1,597 ticks, and 70 miscellaneous arthropods and pentastomes.

Miscellaneous identifications in 1938 totalled 1,700, 250 nematodes and acanthocephalids, 200 cestodes, 700 trematodes, including 7 new species and 4 new genera, 500 ticks and 50 miscellaneous arthropods and pentastomes. Allen McIntosh described 20 new species and 4 new genera of trematodes in 1939, along with several additional economically important internal parasites, including rumen flukes, the large American fluke, and the common stomach worm of ruminants, which were found in deer in Florida.

Dr. G. Dikmans, head of Ruminant Parasite Research, in 1945 published a checklist of internal and external parasites of domestic animals in North America. Dr. Dikmans listed 584 species of parasites that had been reported from these animals up to that time. In 1951, Allen McIntosh clarified the confused taxonomy of nematodes of horses by publishing a list of valid names. In 1964, W. W. Becklund published a revised checklist of internal and external parasites of domestic animals in the United States and possessions and in Canada. At this time, Mr. Becklund listed 751 species of parasites as having been reported from these animals.

In 1965 Mr. Becklund discovered that exposure of parasites to anthelmintics caused changes in the structure of the spicules, gubernaculum, dorsal lobe, and supporting ray of the bursa, thus weakening competence to distinguish and to correctly identify species of livestock parasites. Mr. Becklund suggested that this phenomenon might indicate a potential for attenuation, sterilization, and crossimmunization, and for the use of parasites as a sensitive criterion of teratogenic effects, a new and special dimension to parasitological research. Becklund also published descriptions and keys to many common nematode parasites of ruminants in 1968, and with Martha Walker Hood published a checklist of the internal and external parasites of deer in North America in 1970.

Coincident with the separation in November 1970 from ARS of the Animal Health Inspection Service (AHIS); redesignated in 1971, the Animal and Plant Health Inspection Service (APHIS), staff devoted to systematics was severely reduced and the identification service functions became part of the APHIS responsibility.

In 1972, Maybelle Chitwood and J. Ralph Lichtenfels published the first manual for the identification of parasites in tissue sections, including 259 figures of parasites in lesions, and in 1975 Dr. Lichtenfels published illustrated keys to genera and species of helminth parasites of domestic equids with emphasis on North American forms. This publication has become the standard basic reference around the world.

As a part of an international effort to produce a standard guide for the identification of nematode parasites of vertebrates, new keys have been developed for 108 genera and subgenera of hookworms and strongyloid nematodes. These include many pathogenic parasites of horses, cattle, sheep, pigs, dogs, cats, and man. The new keys, the first to reflect host and parasite co-evolution, provide a necessary working tool for all research on these important nematode parasites. The new classifications and keys are greatly improved in their predictive value over previous systems. Keys to the helminth parasites of ruminants are being prepared and keys to the helminth parasites of swine and poultry will follow.

Patricia A. Pilitt, daughter of the late Dr. Allen McIntosh, who for many years was in charge of the Parasite Classification and Distribution Unit, is carrying on the family tradition as a zoologist and support scientist in the new Biosystematics Laboratory. She transferred to Animal Parasitology Institute in 1977 after 10 years' research experience in the Nematology Laboratory of the Plant Protection Institute, Beltsville, MD. She was senior author of two papers published in 1979, and co-author of several papers on the morphology of ascarids and trichostrongyles, useful in separating species and developmental stages of parasites. She assists in research on nematodes of domestic animals, accessions all specimens deposited in The National Parasite Collection, and processes all requests for loans of specimens from that collection of nematodes. These new capabilities should permit greatly improved diagnosis, treatment, and control of nematode parasites of domestic animals. Biochemical systematics will be emphasized in the newly formed Biosystematic Parasitology Laboratory.

THE U.S. NATIONAL PARASITE COLLECTION

The U.S. National Parasite Collection is one of 13 major systematic collections supported by ARS. Several of them are over 100 years old and contain thousands of specimens; one, the Entomological Collection of the Systematic

Entomology Laboratory, Insect Identification and Beneficial Insect Introduction Institute, Beltsville, MD, combined with the entomological collection of the National Museum of Natural History, Washington, DC, totals more than 24 million accessions. These collections are among the most extensive in the world and have a wide influence on international biological research.

The Parasitè Collection of the BAI (a collection of fixed specimens) was started in 1891 by Drs. Stiles and Hassall. In 1894 a catalogue of the parasites in the collection was published. Shortly after the Zoological Laboratory officially became the Zoological Division in 1906, the division chief was made an honorary curator of the U.S. National Museum of the Smithsonian Institution. This designation simplified the deposition of specimens in the museum's helminthological collection.

In 1927 the two collections together comprised about 22,000 lots of specimens (one lot could be one or several hundred parasites). The division had also accumulated 7,000 drawings, 1,850 photographs and 340 lantern slides illustrating parasites and parasitic conditions. From 1927 through 1939 the number of lots of specimens deposited annually in the two collections ranged from 120 to 2,901 (average 1,073). At the close of 1939 the collections had increased to 35,321 lots. By 1969 the number of specimen lots, including specimens from several privately owned collections that had been deposited in the government-owned parasite collections by their owners, had increased to 65,000.

In 1969 W. W. Becklund described the role of the parasite collection in veterinary parasitology as follows: "It helps to define what parasites cause disease, it provides information on their geographical distribution and animal hosts and on the diagnostic characters by which the parasites may be identified, including their immature forms. This information is essential for treatment, control, quarantine and for research purposes. Furthermore, it also provides information on probable transmission of parasites between domestic and wild animals." (Thirty-six of the 51 species of parasites reported for Bighorn sheep in 1969 were also parasites of domestic sheep and 18 species were found to parasitize cattle in North America).

The U.S. National Parasite Collection has also provided specimens for evaluating malformations of parasites resulting from exposure to antiparasitic chemicals, from irradiation of larvae used to produce immunity in animals, or from adverse environmental conditions that affect the host or the parasite. Now that some parasites can be reared throughout their life cycle without the host by *in vitro* cultivation, these unique parasites are being compared with specimens from animals to establish their normality before their cultivation is considered a complete success. Parasites grown *in vitro* were entered in the collection in 1965 by Dr. E. L. Schiller of the Johns Hopkins School of Hygiene and Public Health.

In 1978 a check-list of type specimens in the collection was published as Special Publication No. 4 of the Index-Catalogue of Medical and Veterinary Zoology. The collection, now designated by one title, "The U.S. National Parasite Collection," in 1984 comprised more than 80,000 specimen lots. This collection is located in the Biosystematics Laboratory, API, BARC-East, Beltsville, MD, 20705. Specimens, including types, are available for loan from the collection. The loans are for 2 months and the specimens are mailed free to researchers. The parasite specimens loaned cannot be used for exhibit or for teaching purposes. The investigator who wishes to take advantage of this service should specify the parasite genus and species, host name, if applicable, and accession number of the museum specimen, if mentioned in the zoologic literature.

The collection has recently been placed in metal cabinets that can be closed and locked, so that, for the first time since it was moved to Beltsville in the 1940's, it is protected from possible destruction by fire.

FUTURE OF ANIMAL PARASITOLOGY RESEARCH

It is expected that the aims of parasitological research will continue as has been traditional for generations: Taxonomy and classification; life histories and parasite distribution; pathogenicity; and means of preventing infection and/or removal from the host. However, the recent acquisition of more detailed and precise knowledge in biochemistry, molecular biology, and immunology has brought a profound change in the methods of parasitological research at the present time and for the forseeable future.

Dr. Harry Danforth, a research microbiologist, Protozoan Diseases Laboratory, at the Animal Parasitology Institute, Beltsville and his colleagues have produced hundreds of monoclonal antibodies to chicken coccidiosis, caused by coccidia belonging to the genus *Eimeria*. However, there is no vaccine yet, and it may be years before one sees the light of day.

Antibodies against the coccidia proteins are being made via the hybridoma technique in which spleen cells from mice inoculated with the coccidial parasite are fused with mouse cancer cells that grow with cell culture. The resulting fused cells have the immortality of cancer cells in culture and in addition they produce a single antibody (monoclonal antibody) against the disease-related coccidial parasite protein. Danforth said that 10 of the cloned cell lines were designed to produce antibodies against *E. tenella*, but he and his colleagues are currently producing monoclonal antibodies against several other species of chicken coccidia. These antibodies may someday be the basis for identifying antigens that could serve as a source of vaccine and may also be used to diagnose the presence of coccidia in chickens and to determine whether the chickens have developed immunity to the disease.

According to an Agriculture Department press release, dated July 1983, genetically engineered proteins, required as a first step in devising a potential vaccine against a serious disease of poultry, will be produced by three companies under agreements with the U.S. Department of Agriculture. Dr. Danforth said that the goal is to develop a broad-range vaccine against coccidiosis. This parasitic intestinal disease complex annually costs the U.S. poultry industry more than $150 million in direct losses and about $100 million for anticoccidial drugs, he added. According to the agreement, proteins called antigens will be identified by use of monoclonal antibodies furnished by the Poultry Parasitic Diseases Laboratory at Beltsville.

The above is only one example of the forward-looking research now being carried on at the Animal Parasitology Institute. Similar work is being done by K. Darwin Murrell and his colleagues of the Nonruminant Parasitic Diseases Laboratory in an attempt to isolate antigens that may serve as a vaccine against trichiniasis in swine and that could be used to detect hogs infected with *Trichinella spiralis* at the time of slaughter. This vaccine would enable the trichinous carcasses to be identified and segregated for further processing to kill the parasites and the remainder could be guaranteed trichina-free.

At the present time, it appears that while traditional parasitological research will continue, expedited by new tools and new discoveries, the microbiologist, the molecular chemist, and the immunologist have found secure places in the parasite research of today and that of the next century.

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PART V
MEAT AND POULTRY INSPECTION IN THE UNITED STATES DEPARTMENT OF AGRICULTURE

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BACKGROUND

The post-Civil War years were years of great change in the marketing of livestock in the United States. Up to that time, livestock production and marketing substantially were a local affair; most meat animals were slaughtered and consumed in the same area where they were produced. But with the opening of the Western Plains to cattle production and the availability of Midwestern corn for swine feeding, production of livestock became concentrated in the center of the Nation.

The cattle drives from Texas to northern markets or railheads captured the public's attention. The expanding railroads provided transportation for livestock to markets where they were slaughtered. Before the Civil War, there were few refrigeration facilities for meat after slaughtering or during distribution. Some experiments were undertaken to develop refrigerated freight cars, but a practical car was not developed until later. One contributor to the 1870 annual report of the Commissioner of Agriculture discussed problems of transporting livestock in the United States and the fact that much of the meat was unfit for human use. Refrigeration by natural ice was increasingly applied to food preservation. After the War meat packers in the interior cities, especially the prominent "Big Five" companies which dominated the industry, built their own refrigerated cars to ship meat to the rapidly growing eastern cities. By 1881 shipping dressed beef from Chicago was well established.

This was an era of few controls and little attention was given to conditions under which the meat was processed as long as it was saleable. Local controls were unevenly applied where existent. The individual States attempted to control or eradicate disease, but they soon found this virtually impossible. Their efforts were spasmodic and quarantines imposed were bitterly resented by other States. The best informed livestock growers and veterinarians were urging a national approach. Much of the pork was processed into ham or bacon or salted or soaked in brine as a means of overcoming problems of preservation.

The year 1875 was heralded as marking a turning point in the history of the meat industry. The development of refrigeration systems for ships enabled the entrepreneurs to enter European markets. Livestock could be slaughtered in New York, cooled, and loaded at night just before the vessel sailed. The refrigerator unit was sealed and opened at the end of the voyage. Ice could be added during the trip from a special supply. After the meat arrived in England, it was quickly shipped to markets where it competed with local products.

An alternative was developed that would overcome problems of getting the meat to market in a satisfactory condition by shipping the animals alive to Europe, where they could be slaughtered as needed. Vessels were modified to care for them; but there were some problems. Many vessels involved in the trade were alleged to be "tramp steamers", poorly fitted for the long ocean voyage, and animals arriving on these were frequently bruised, injured, dead, or in a "most unfavorable" condition. But the trade in live animals increased rapidly, from 109,500 pounds of beef in 1874 to 72,427,000 pounds in 1880. However, various overseas shipping lines soon found that mechanical refrigeration was very practical for transatlantic shipments. The supply of meat from the United States increased and provided greater competition with the provisioners in England and the continent.

MEAT INSPECTION

The outcry against this competition was strong. Charges and counter charges were made. The governments became involved. In 1869, the British Parliament had acted to prevent the introduction of cattle diseases from abroad. British

inspectors claimed that they found cases of pleuropneumonia among American cattle. In 1878, Parliament required that all imports of livestock, except for cattle from exempted countries, be slaughtered at port of entry. Only American cattle with a government health certificate were to be admitted. Actually there was no real provision for such certification in the United States. The Secretary of the Treasury authorized collectors of customs to "cause" inspection to be made of Britain-bound cattle, but the collectors were not trained for such work. Another Treasury circular of February 1, 1879, made inspection imperative and required reports on diseases found. Later that month, the Department issued another order prohibiting the loading of cattle for British ports. Roughly six months later this was replaced by a ninety day quarantine before shipment, that raised a hue and cry in the United States.

Meanwhile, the United States Department of Agriculture had undertaken studies of diseases of livestock in the United States. Charles P. Lyman of Yale University was chosen to head these studies and in 1879 was sent to England to investigate the existence of pleuropneumonia among U.S. cattle that had been shipped there. He did find some, but a heated controversy ensued about its origin. Already some were concerned about the transferability of diseases from animals to humans. Thus a National Board of Health was established in the United States in March 1879, that sought jurisdiction over both human and animal health. Though its assigned area was human health, it made studies of animal diseases.

In 1881, the Secretary of the Treasury appointed the Treasury Cattle Commission to study the livestock disease situation in this country and to develop a program to prevent incursion of a scourge that could ruin the western livestock industry that was supplying some of the criticized exports. The Treasury Department imposed a 90 day quarantine on imported cattle and established four quarantine stations in 1883. The following year these were to be transferred to the newly established Bureau of Animal Industry.

European countries had also placed restrictions on the importation of pork from the United States on the grounds that it was infested with trichinosis and that many U.S. hogs had hog cholera. In 1883, Secretary of State Folger asked George Bailey Loring, Commissioner of the Department of Agriculture, to appoint two representatives to a commission to study pork production and processing and European restrictions on U.S. trade. In its report, the commission defended the domestic pork and suggested that microscopic examinations be instituted if trade required it. Seven years were to elapse before the inspection was implemented. But producers and packers continued to urge the Federal government to undertake a program that would enable them to convince European governments that U.S. livestock products were safe for importation and thus enable them to enter foreign markets closed to them. As part of the effort, they actively supported the establishment of an agency in the Department of Agriculture to conduct the work.

A veterinary division and experiment station were inaugurated in the U.S. Department of Agriculture in 1883. The work was expanded in the establishment of the Bureau of Animal Industry in 1884. One of the missions was to prevent exportation of diseased cattle. Limited by law at first to twenty employees, the Bureau of Animal Industry devoted much of its efforts in the 1880's to an uphill battle against diseases. But even before the personnel restriction was lifted, its work had been expanded to include the operation of four quarantine stations to protect our expanding livestock industry against foreign diseases.

These were the years of a rapidly growing livestock industry that was seeking expanding markets overseas. Reports of animal diseases in the United States spread throughout potential market areas in Europe. Most writers of the time admitted that there were many areas where there were diseases. However, many of the exported cattle had been raised in western areas where the diseases had not yet spread. In fact, that had been a factor in instituting the disease control work of the Bureau.

England and the continental European countries continued their restrictions of American imports. The livestock from the United States were still being slaughtered upon their arrival in England. Nonetheless, the U.S. imports increased rapidly. An Edinburgh journal reported that in 1889 not less than 4 million hundred-weight of beef came in.

The pressures increased from the livestock industry, the packers, the livestock press, and veterinary groups for action which would meet some of the objections of Britain and European countries, whether they be based on disease conditions or economic motives. Representatives appeared before both houses of Congress seeking relief, and the livestock exchanges favored legislation for Federal protection.

On May 10, 1888, the United States Senate passed a resolution providing for a special committee of five senators to study the transportation and sale of meat products in the U.S. It held hearings in a number of cities. Its voluminous

report submitted in 1890 discussed the existent situation with confusion between State and municipal authorities inspecting livestock and meat and the fact that they had control over only trade within the immediate State. The committee recommended the institution of Federal inspection of animals and meat products to benefit our citizens and protect our overseas markets.

The Meat Inspection Act of 1890

The first meat inspection act was enacted and approved by President Benjamin Harrison on August 30, 1890. It authorized the Secretary of Agriculture to provide for the inspection of salted pork and bacon intended for export whenever a foreign government requested it. The inspection was to be made where the meat was packed or boxed, or at the place of exportation, if the Secretary determined that a reinspection was necessary. Certificates of wholesomeness were to be issued and the packages marked or stamped to indicate approval.

Other provisions of the act related to regulation of imports of food or drinks. Livestock being imported were subject to quarantine at the owners' expense at the established ports of entry. It allowed the Secretary of Agriculture to provide for the inspection of live animals for export and inspection and disinfection of all vessels handling the livestock—at the expense of the owners of the vessels. Regulations were soon issued by the Chief of the Bureau of Animal Industry. The implementation of the law showed many loopholes.

A more stringent law was approved on March 3, 1891. The Secretary was to have "careful inspection" made of all cattle being exported and the vessels carrying such animals were not to be cleared for departure without a certificate of inspection signed by a USDA inspector. Moreover, live cattle, whose meat was to be exported, were subject to inspection to determine if the animals were free of disease and their meat wholesome. The vessels carrying fresh beef were not to be given clearance unless an inspection certificate had been issued by USDA. All cattle, sheep, and hogs whose meat was to be shipped in interstate commerce were to be inspected prior to slaughter; in addition, the Secretary might direct post-mortem examination of carcasses at slaughter houses or processing plants. Carcasses were to be labelled to show inspection.

Meat inspection expanded rapidly following the passage of the 1891 act. The microscopic inspection of pork for trichinosis involved a large staff of assistant microscopists, many of whom were women, in major inspection centers—Chicago, Buffalo, Boston, Cincinnati, Cleveland, Kansas City, Omaha, Indianapolis, Milwaukee, Ottumwa, Cedar Rapids, Sioux City, and South St. Joseph.

A typical microscopic inspection center. Here a staff of 60 men and women inspect pork samples for signs of trichinosis.

In the first three years of the broadened meat inspection act (May 1891-July 1894) some interesting facts were revealed in the annual reports of the Bureau of Animal Industry. The number of packages of canned, salted, or smoked meat increased from nearly 800,000 packages to over a million. Microscopic examinations of hog carcasses covered over a million carcasses in the first year, nearly two million in 1893, and about one million, four hundred thousand

in 1894. Although much of the effort for passage of the 1890 and 1891 legislation was to protect our export market, the domestic market benefitted from it also. In 1892, 1,190,771 beef quarters were inspected for export and 8,160,620 for interstate trade were inspected. In 1893, the number for export declined to 1,036,809 while the interstate increased to 10,534,102. In 1894, the number inspected for export increased to 2,417,312 and for interstate commerce amounted to 10,810,202. In addition, sheep and calf carcasses were inspected. By this time the meat inspection work had became the most extensive activity of the Bureau of Animal Industry. Inspection was carried on at 46 abattoirs in 17 cities, an increase from the 22 slaughter houses in the first year of operation.

However, there were problems in implementing the act. Probably the most crucial was the disposition of animals or meat that failed to pass inspection or rejected products that still found their way into trade channels. Moreover, a concern for the consumer was emerging and inspectors were advised to reject animals and meat unfit for food. There was also discussion of the acceptability to the consumer of certain types of meat—from animals that had recently given birth or about to give birth to young—and that such meat or animals should be condemned by inspectors.

Both Secretary Rusk and Secretary Morton asked Congress to strenghten the legislation. Rusk recommended that inspection should cover all animals used for human food. Secretary Morton asked authority to prohibit the movement of condemned carcasses or meat in regular trade channels. He also stated that since the inspection benefitted the packers, they should pay for it. In 1894, pre- and post-mortem inspection were extended to hogs, broadening coverage from the salted pork and bacon that had been covered in 1890.

In 1895, Congress amended the meat inspection act, authorizing the Secretary of Agriculture to issue rules and regulations to prevent the shipment of condemned meat across state or territorial lines or to any foreign country. In practice, the Chief of the Bureau of Animal Industry, D. E. Salmon, arranged agreements with packers and slaughterers.

The appropriation act for fiscal year 1899 entitled live horses and horse meat to the same inspection as other animals and animal products. This was included in the appropriation act through 1903. Only one plant, at Linnton, Oregon, was devoted exclusively to the slaughter of horses; from 1899 to 1903, 12,776 horses were slaughtered for export. After World War I, the question arose again. On July 24, 1919, the Horse Meat Act was approved to provide for the inspection of horses, horse meat, and meat products and for their labelling as such.

Those working in meat inspection realized during the 1890's that there were still problems. Several reports recommended changes to correct defects. Again, in 1897, the House Committee on Agriculture recommended the imposition of a user fee for packers who "enjoy market advantages not possessed by owners of meat not so inspected or certified." The bill failed.

By the turn of the century, the Bureau of Animal Industry had a large number of employees in its meat inspection work: veterinarians, assistant veterinarians, taggers, stock examiners, microscopists, and assistant microscopists. (Some of these had been trained as medical doctors.) They were located in many areas, especially where the animals were slaughtered. And as in later years, some were offered bribes to pass meat that should be condemned or to not enforce rules and regulations of the Bureau.

The problems continued and were discussed in various forums. When the U.S. Industrial Commission made its report on Agriculture and Agricultural Labor in 1901, it deplored the amount of condemned meat that was being sold by slaughterhouses instead of destroyed and recommended Federal legislation to remedy this. Thus, the informal agreements of the Chief of the Bureau of Animal Industry with the slaughterhouses and packers would be replaced by formal regulations under the act of 1906.

Over the years, the number of animals inspected had continued to increase, with those for domestic consumption far outnumbering those for export. Nonetheless, the staff of the Bureau was still unable to service many of the smaller plants. Under the 1890, 1891, and 1895 legislation no provision had been made for maintenance of sanitary conditions at slaughterhouses or packing plants. Finally in February 1906 the Secretary issued regulations providing for cleanliness in all parts of the slaughterhouses.

Over the years the meat inspection work was under attack. Packers complained of what they considered unnecessary restrictions. Other countries charged BAI was too lenient in its inspection. Congressmen sent their complaints to President Roosevelt or to Secretary Wilson. The Secretary would reply that lack of funds at times required personnel cuts. Since the Bureau's appropriations necessitated limitations on expanding the service, charges were made against the

Chief of the Bureau D. E. Salmon that he favored the large packers rather than smaller ones. Then Salmon's connection with the company that printed the meat inspection labels made the newspaper headlines. Secretary Wilson had known of the connection that had been terminated. But President Theodore Roosevelt felt that the affair should be turned over to the Justice Department. Salmon resigned. Thus when Upton Sinclair's *The Jungle* precipitated an uproar over conditions in the packing and slaughterhouses in 1906, Secretary Wilson bore the brunt of the criticism. Before that he had defended some of the inadequacies of the administration of the inspection program on the basis of insufficient funds. In 1906 he wrote that only $63,000 had been appropriated.

Sinclair's novel described the experiences of an employee of supposedly one of the big slaugterhouses. His graphic depiction of the unsanitary conditions stirred public opinion. Thus, *The Jungle* provided an immediate stimulus for legislation in 1906 to improve the meat inspection service. James R. Garfield, Chief of the Bureau of Corporations, sent a copy to the President, before the President received one from the author. Roosevelt took Sinclair's description of conditions in the Chicago meat packing houses seriously.

On the other hand, Secretary of Agriculture James Wilson attached less importance to *The Jungle*. He wrote to a Congressman "A fellow named Sinclair wrote a book called *"The Jungle"* grossly misrepresenting conditions in our packing houses. . . . It is having a considerable sale, I understand, in foreign countries where our meats go." He followed this up with a letter to the Postmaster-General asking that he review a marked copy of the book to determine whether it should be excluded from the mails. He went on to say "The matter contained in these pages seems to me beyond the shadow of a doubt, to be impure, indecent, and obscene." However, the book continued to be sold and was widely circulated, focusing criticism on the Department's administration of the meat inspection program in the Chicago area.

Soon, however, Wilson did take positive measures. On March 2, 1906, he asked John R. Mohler, chief of the Pathological Division; Rice P. Steddom, chief of the Inspection Division, who had supervision of the meat inspection work; and George P. McCabe, solicitor of the Department, to be a committee to investigate conditions at the Chicago abattoirs—the work of BAI, relations with the city meat inspection service, and the sanitary conditions at the abattoirs.

Thus when President Roosevelt contacted the Secretary of Agriculture, he found that Wilson had already appointed an investigative committee. The President insisted that the investigation be thorough. At Wilson's suggestion, Roosevelt appointed his own committee headed by Charles P. Neill, Commissioner of Labor, and James R. Reynolds, a New York lawyer.

The members of USDA's committee to investigate conditions in Chicago left Washington on March 10, 1906, and spent 10 days visiting the abattoirs having Federal inspection service and two that were not so covered. Generally, the calls were unannounced and the committee was assisted by a Government employee stationed at the plant.

The report of the committee was made to the chief of the Bureau of Animal Industry on April 3, 1906 and to the Secretary of Agriculture on April 5, 1906. It covered the following points:

Ante mortem meat inspection
Post mortem inspection
Meat inspection by the State of Illinois
Meat inspection by the city of Chicago
Government supervision of canned products
Sanitary conditions in each location
Legal phases including scope of authority of the Federal Government, the State, and the city.
Conclusions and recommendations.

The committee urged that Federal inspectors be required by law to mark and "render unfit for food purposes" carcasses of cattle, sheep, and swine found to be diseased, unwholesome, unsound, and unfit for human consumption. All meat entering in interstate trade would be required to be passed by Federal inspection. Microscopic inspection of pork for export should be at the expense of the establishment where it was inspected. It urged that the Secretary be directed by law to make rules and regulations covering sanitary conditions at slaughtering and processing plants for meat entering in interstate or foreign trade. It recommended an increase in the staff of the meat inspection service to adequately perform the expanded duties. Other recommendations covered physical conditions, the handling of disposable material, and related activities. The report closed with a statement that the Federal workers in Chicago were

doing their full duty. However, the staff was numerically inadequate for the task.

When Wilson sent his report to the President, Roosevelt referred it to a committee for evaluation. Charles P. Neill, its chairman, was extremely critical of the USDA report. At the President's request, some parts were rewritten and when the chairman of the House Committee on Agriculture reviewed USDA's and the Roosevelt committee report, he found general agreement.

Secretary Wilson had the Department's solicitor George P. McCabe draft legislation to meet what he felt the situation required. The bill would have required the packers to pay for the service and would have insured funds for the work unaffected by Congressional restraints. The proposed legislation was sent to the President and then to Senator Albert O. Beveridge. It passed the Senate and then languished in the House of Representatives. Almost simultaneously pressure from the public and the President resulted in an improved act.

The Meat Inspection Act of 1906

The Meat Inspection Act of 1906 was a section of the Department's annual appropriation act. It was originally written by Senator Albert Beveridge and was referred to as the Beveridge Amendment. The act was approved on June 30, 1906. Under this legislation the authority of the Secretary of Agriculture was increased to carry out a more effective meat inspection program to insure that meat and meat products entering in interstate and foreign commerce should be wholesome, healthful, and fit for human consumption and should be produced under sanitary conditions. The animals were to be inspected both before and after slaughter and the meat processing was to be reviewed to insure that the required USDA "inspected and passed" mark, stamp label, or tag was a proof of its quality. Products that bore the "inspected and condemned" designation were to be destroyed for food use in the presence of the inspector. If this was not done, the Secretary was authorized to withdraw the inspectors from the plant. Slaughterhouses, meat packing and processing plants whose products entered in interstate or export trade were to be inspected for sanitary conditions by "experts in sanitation"—a new function for the Bureau of Animal Industry. In fact, this represented a new direction for USDA to benefit the consumer as well as the producer.

Cattle designated as "suspect" undergo examination before receiving the classification "inspected and condemned."

Similarly, livestock for export were to be inspected for disease and certificates issued to signify this. Again, the vessels exporting such animals or meat products were not to be given clearance unless cattle on board had been inspected and passed. The act also specified that there should be an examination for dyes, chemicals, preservatives or other ingredients that would make the inspected products unfit for human food. The Secretary was to issue rules and regulations for the administration of the program. Moreover, definite provisions were included for the punishment of those who tried to bribe or otherwise pay USDA personnel administering the inspection. Similarly, USDA personnel were subject to criminal prosecution for taking payment for such activities.

Although Secretary Wilson felt that $100,000 would provide adequate financing, the act of 1906 appropriated an amount of $3,000,000. A year later the act was reenacted. The permanent three million dollar appropriation was changed to an annual appropriation. The total appropriation for all work of the Bureau for 1907 amounted to $1,032,480. The change was made to ensure continuous authority rather than year by year.

The Department discontinued the microscopic examination of pork when the new program went into effect. The rapid expansion of the work meant a rapid expansion of personnel, from about 760 employees in 1906 that included about 300 veterinary inspectors, to 3,380 employees in 1908 of whom 620 were veterinarians.

In the 1906 report of the Bureau of Animal Industry, Alonzo E. Melvin, the new chief of the Bureau, included an article "The Federal Meat-Inspection Service," in which he traced the history of this work. His twenty years of personal involvement in the program enabled him to present USDA's efforts and viewpoint of the expanded program under the Meat Inspection Act of 1906. He compared the inspection system in the United States with that in other countries.

Secretary Wilson took a personal interest in the administration of the new legislation. He reported to President Theodore Roosevelt later in 1906 that he had visited Chicago and various large cities where extensive packing was conducted and had talked with superintendents and packers. He was looking forward to a Federal meat inspection program in plants that were making strenuous efforts to be ready for inspection. Their products would move in interstate and foreign commerce. Their operations would provide a sharp contrast to those under State and city inspection that seemed to be paying little attention to sanitary conditions.

On December 21, 1906, Secretary Wilson invited seven experts to serve on a commission to consider USDA's regulations for the disposition of diseased and abnormal cattle. Three days of meetings were held in February 1907. John R. Mohler of BAI assisted the commission. It suggested that the Bureau prepare circulars explaining the various paragraphs of the regulations covering meat inspection. The commission found that the principal disease for which animals were condemned was tuberculosis and recommended a number of amendments to existent procedures.

Following the passage of the meat inspection act, the work grew rapidly. Arthur Farrington, assistant chief of the Bureau of Animal Industry, reported that in fiscal year 1905-1906, $771,661 was expended on 981 employees in 163 establishments in 58 cities. During 1906-1907 this had increased to $2,159,474 for 2,290 employees at 708 establishments in 186 cities and towns.

In this period of rapid growth the meat inspection service was beset with problems and criticism. There were charges that little change had taken place since the passage of the act. Congressional hearings were held, providing a floor for the criticism.

By 1908, Farrington was urging that State and municipal meat inspection programs be strengthened to supplement the Federal system. He had found many of the non-Federally inspected establishments in a most unsanitary condition. Where there was inspection, it was sometimes conducted by unqualified people; where qualified employees were inspecting the slaughter and packing operations, the staff so involved was most inadequate. Unless action was taken, he saw a tragic dichotomy, since the Federal system covered only establishments involved in interstate or export trade.

The early meat inspection did not cover poultry or fish or related products. However, the Food Research Laboratory of the Bureau of Chemistry conducted studies, as early as 1908, of poultry slaughter, transportation, and the handling and storage of fish to insure better food for the consumer. These were continued until the inspection was made compulsory several decades later.

Responsibility for investigations of chemicals in meat and meat products necessary to the meat inspection work was delegated to the Biochemic Division of BAI. As early as 1896, the Division had been doing some chemical work on

meat products. A central laboratory was established in Washington under the new law with branch laboratories in other cities. These checked especially on preservatives or harmful substances and cereals in meats and meat products and whether the meat and meat products were properly labelled. In 1914, when research and regulatory work was separated within the various bureaus in USDA, meat inspection research was transferred to the Meat Inspection Division.

In a period of reappraisal of the structure of government and its role, various suggestions surfaced. Senator Owen of Oklahoma suggested in 1912 that a National Health Service be established to include the transfer from USDA of the administration of the Food and Drugs Act and the Meat Inspection Act as well as certain entomological functions. Secretary Wilson objected. He strongly supported the veterinarians who were working on the USDA implementation of the meat inspection law. Shortly thereafter, the Inspection Division was abolished, to be replaced in part by the Meat Inspection Division, a status the work would continue to retain through numerous reorganizations.

Inspection of Imported Meat

Imported meat and meat products were brought under compulsory inspection and the meat inspection program by paragraph 545 of the Underwood Tariff Act, approved October 3, 1913. In anticipation of this, A. D. Melvin, who had become chief of the Bureau of Animal Industry, visited certain South American countries to compare systems there with those in the United States. Later that year E. C. Joss made a similar survey in Australia and New Zealand. The Department could, it was felt, effectively establish an inspection program for imported meat and meat products.

BAI Regulation 27, spelling out procedures to be followed for a program for such commodities, was effective January 1, 1915. This required that the imported meat should be processed by an inspection system equivalent to that of the United States. Consignments of meat were to have certificates specifying the comparability. Upon its arrival in the United States, the meat was to be reinspected by USDA inspectors. Inspection was continued, but little mention was made of equivalency of foreign and domestic inspection systems. Products inspected under this program came especially from Australia, New Zealand, Canada, Argentina, and Uruguay in the 1920's, but in the 1930's a number of European countries sent their products through the system.

Another factor affecting the imported meat picture was the spread of disease. The 1920's had seen an increase in foot-and-mouth disease. This led to the inclusion in 1930 in the Smoot-Hawley Tariff Act of a provision prohibiting the importation of livestock from countries where foot-and-mouth disease was present. It also specified that imported meat must be healthful, wholesome, and fit for human food. After entry it was subject to the same standards as domestic meat.

The inspection of imported meat continued to be controlled by the provisions of the 1930 tariff act for the next 33 years until the act was amended. In 1963, legislation for the import inspection work was updated and authorized the President to establish or lift quotas for imports of meat, based on domestic production.

When the Wholesome Meat Act was passed in 1967 to improve the overall meat inspection system, it extended the coverage of the act to require foreign inspection systems to be "equal to" rather than "substantially equivalent to" the U.S. system. The number of inspectors based in the U.S. to check on overseas inspection was increased from 8 to 13. It was expected that each overseas plant would be inspected at least once a year and problem plants more frequently. Soon they reviewed sanitation conditions in 88 plants that showed need for improvement. Experience by 1971 indicated the expediency of stationing six foreign program officers overseas and the need for the foreign program review staff to be increased to provide more frequent reviews of plants shipping larger quantities of meat. The foreign or import inspection work has been administered to insure that imported products were subject to the same standards as domestic meat and poultry.

The Foreign Programs Division of FSIS now has the responsibility of determining whether or not a foreign country can export meat or poultry into the United States. United States law permits the importation of meat or poultry from those countries that are recognized as having meat inspection laws, regulations, and a system of meat inspection that is "equal to" the United States domestic meat inspection system.

The foreign country must first request recognition to become eligible to export meat and/or poultry into the United States. This is accomplished by sending a request in the form of a diplomatic note through the United States embassy in the foreign country or through the foreign country's embassy in Washington, DC. The foreign country's meat and/or poultry inspection laws and regulations usually accompany the diplomatic note. The Foreign Programs Staff reviews

the foreign country's meat and/or poultry inspection laws and regulations and determines whether or not they are "equal to" those of the United States.

The foreign official in charge of meat inspection is notified that his country's laws and regulations are found to be "equal to" those of the United States. Following this, the foreign officials in charge of meat inspection identify those plants in the country that are most likely to meet United States requirements. Onsite review of the foreign country's meat and/or poultry inspection system (including plants) is made by a U.S. Foreign Programs Officer or a team of FSIS inspection personnel to determine if the foreign system is equal to the United States domestic system. When the foreign meat inspection system is found to be "equal to" the U.S. system the foreign meat inspection official certifies those plants that he recognizes as meeting United States requirements.

The Foreign Programs Staff uses data obtained from the foreign country along with its knowledge of the country's meat inspection system to prepare a profile of the country. The Staff then establishes the frequency of reviews of the foreign country's meat inspection system. The program is conducted by officials and inspectors of the foreign government.

The U.S. Foreign Programs Officers make reviews of the foreign country's meat inspection system and report their observations to Foreign Programs Staff in Washington, DC. In cases of system wide serious deficiencies that are not corrected by the foreign officials, the Deputy Administrator of International Programs, FSIS, USDA, notifies the foreign country that it has lost its eligibility to export meat into the United States. The country is then removed from the list of countries recognized as eligible to export meat into the United States. In serious cases that are localized in a single meat plant, that plant is removed from the U.S. list of exporting plants. Less serious technical problems that are corrected permit continued acceptance by USDA of the units involved.

All meat imported comes from authorized plants in recognized countries and is accompanied by a sanitation certificate issued by a qualified representative of the exporting country. Upon their arrival at port of entry, U.S. inspectors take representative samples for examination to determine that they meet U.S. standards for meat inspection.

The inspectors of imported meat make startling discoveries at times that have far-reaching effects. In mid 1981, it was announced that a shipment of boneless beef from Australia had horse meat in it. About 7,000 pounds of a 36,000 pound shipment had been consumed but a definite determination could not be made of the amount of horse meat. Subsequent investigations resulted in the embargo of other meat from the same facility. Then the Australian government found meat destined for the U.S. on the docks was actually kangaroo meat as well as horse meat. The Australian government reacted by delisting the producing company, pending its investigation of the situation. Another investigation was undertaken by the Australian police. A Royal Commission was appointed to review the situation. This made a number of recommendations to remedy the situation. It singled out the Bureau of Animal Health for its supervision of the work. It was also critical of the hodge podge of Commonwealth, State, and Municipal inspection services and urged that a national meat inspection service be established.

In 1982, the Export Control Act became law and a new Export Inspection Service was established in Australia to have charge of all exports. A new system of regulations and orders was set up; greater emphasis was given to management activities. As the reorganization was implemented a number of lateral personnel changes were made. A more stringent system for imposition of penalties for infractions of the controls was implemented. A number of offenders have been prosecuted including some inspection personnel and some cases are still in process. The Australian Commonwealth government has made a beginning toward a national meat inspection system by taking over that of New South Wales. In 1986, Victoria was included in the system.

The United States also took steps to protect American consumers in the future. Boneless meat leaving Australia was to be tested for species by that Government and kept under security until it reached the U.S.. Meat already enroute from Australia was to be held at port of entry and tested for species before entering this country. Moreover, countries shipping boneless meat to the U.S. were to be notified that they must have a species determination program. Regardless of country, all fresh meat and frozen boneless meat was subject to spot-check inspection in the U.S. Subsequently, the Agricultural Act of 1981 amended the Meat Inspection Act to require that imported meat and meat products were subject to the same standards and species verification as domestic products. As programs were reviewed, a number were found deficient in their programs for species verification. Fourteen countries were notified they would no longer be eligible to export meat to the United States.

As this problem was being resolved, a rule was issued in August 1982, to dispose of the meat and poultry that had been refused entry to the United States. Some of this had found its way into the domestic market instead of being returned to place of origin or otherwise disposed of. Under this provision, USDA assumed full responsibility for security over such products instead of sharing it with the U.S. Customs Service.

The General Accounting Office (GAO) has made investigations of the inspection of meat imports. In late 1970, GAO undertook an investigation of the program. By this time the inspection systems of 42 countries had been approved by the Consumer and Marketing Service (CMS); 37 of these countries had 977 plants certified for export to the United States. Eleven foreign program officers were assigned to review these plants. By November 1971 the number had increased to 18.

Each GAO staff member was accompanied by a foreign programs officer as he or she made their review of selected plants in Australia, Argentina, Denmark, and Canada. They found great variations in the plants visited. Some plants were delisted as a result of the reviews. But in some instances meat continued to be shipped. Followup visits were made to plants where violations of the meat inspection regulations were found.

GAO recommended that CMS authorize its foreign programs officers to provisionally delist plants not in compliance and to suspend the shipment of most products to the United States; prohibit the importation of meat processed prior to delisting when they were determined to be harmful, unwholesome, or unfit for human food; and strenghthen the review force by increasing the number of foreign programs officers overseas to increase the rate of review. The imports of meat were also subject to inspection at ports of entry by CMS personnel. GAO found that the sampling procedures followed were quite inadequate.

A month later Brian Crowley discussed the situation before the House Agriculture Committee. Crowley reported that the GAO had found that the foreign inspection systems were not necessarily equal to that of the United States. A FSIS staff officer had reported that he was working with some of the countries to achieve such comparability. The Service was also working on a systems approach to assess the foreign inspection system.

Crowley indicated that the United States system of inspection at ports of entry was unevenly applied. In part, this was due to unequal staffing and to the thoroughness of inspection. Some problems had arisen from the inauguration of the Services Automated Import Information System without updating its regulations and manual. He reported that differences in procedures resulted from lack of a clear understanding of what was expected. Most of the inspectors interviewed felt that periodic training should be given. Crowley discussed the widespread supervision problems and the lack of supervisors' review of inspection records at ports of entry.

Another report of the General Accounting Office, submitted in June 1983, turned again to the inspection program because of Congressional and public concern about the program's effectiveness in providing imports of wholesome, unadulterated, and properly labeled products. GAO investigators and five representatives of FSIS visited 82 foreign plants in four countries and found only 4 rated unacceptable and delisted by FSIS. Six other plants had one or more areas of noncompliance. However, program changes were needed to insure that the imported products met U.S. requirements.

Imports must come from countries that have an FSIS approved inspection system equivalent to U.S. requirements for its system. Plants certified to enter the export trade with the U.S. are checked for effective enforcement of laws and regulations. Then the Foreign Programs Officers periodically review the plants for compliance with U.S. regulations on inspection, plant facilities, and sanitation.

GAO recommended that FSIS revise its meat inspection manual to specify procedures that Foreign Programs Officers were to follow in reviewing plants; develop more uniform and objective directions for reviewing and rating foreign plants; revise the form for foreign plant reviews to insure complete and consistent ratings and to identify problems for followup; direct foreign inspection officials that they are responsible for correcting deficiencies and delisting plants not in compliance; and to develop a systematic compilation of foreign inspection systems with U.S. requirements. Periodic reviews should be made of other plants as necessary, at least annually.

USDA's comments on the report and GAO's evaluation of these comments showed quite a variance in attitude toward the operation of the foreign inspection system, with the Department following a broader approach and GAO stressing the need for a more specific implementation.

Cooperation with Other Departments

The Bureau of Animal Industry cooperated with other Federal agencies in inspecting and reinspecting meat and meat products procured under specifications. While the Army had had some veterinarians in its service, they were assigned to the care of animals. Following the furor over the much publicized "embalmed beef," a veterinarian was transferred in 1901 from BAI to the War Department. There he was to be a meat inspector at large for the Subsistence Department of the United States Army.

Following the passage of the Meat Inspection Act of 1906 and the expansion of the staff engaged in this work, the Navy Department in 1907 asked BAI to reinspect meat and food products purchased and delivered to naval vessels and stations in Boston, New York, Philadelphia, Norfolk, New Orleans, and San Francisco. Subsequently, it extended reinspection to all important naval bases and establisheents. The service was continued for many years and usually constituted the bulk of the products inspected for government agencies. Volume expanded or contracted as the activities of the Navy changed.

Moreover, long before the Department was inspecting eggs for the market and the public, it performed this function for the Navy Department. In 1912, 45,862 dozen were inspected; in 1913, 70,140; and in 1914, 107,380.

When the United States entered World War I, the War Department asked the Bureau to assist in the inspection of meat for the Army. Sixty four meat inspectors were detailed to various Army installations. Thus in one year such work quadrupled, placing a heavy drain on the Division's resources. Some of this was relieved when the Army's Veterinary Corps was established, but some continued. During the early 1930's the work again increased when over a million pounds were checked annually in 1930, 1931 and 1932. The ensuing years saw a steady decline in such service for the Army.

A number of other agencies entered into cooperative arrangements for meat inspection. Work for the Marine Corps began in 1919. The Bureau of Indian Affairs, under Cato Sells, had USDA inspect its meat and meat products to be distributed on Indian reservations from 1916 on. The Veteran's Bureau, with its expanded clientele of servicemen serving in World War I, took advantage of USDA's services beginning in 1927 with nearly 300,000 pounds of meat and meat products. Administrative officials of the Federal penitentiaries of the Department of Justice joined other agencies as they sought the assistance of USDA in checking their meat and meat products.

Other agencies that utilized this service of BAI intermittently, for lesser amounts or for short periods of time included: Public Health Service, Coast Guard, Shipping Board, Panama and Alaska railroads, Forest Service, National Homes Service, Tennessee Valley Authority, and the National Zoological Park. Many agreements have been necessary to coordinate this interdepartmental cooperation in meat inspection activities.

Much of this work for other agencies and departments was essentially certification that the meat and meat products met established grades and standards. The function was therefore transferred from the meat inspection unit and became a part of the meat grades and standards unit currently in the Agricultural Marketing Service.

The table that follows was prepared from the annual reports of the Bureau, giving the total number of pounds of meat and meat products inspected. The agencies reimbursed the Department, enabling it to expand this function beyond the available appropriated funds. Thus more people benefitted from BAI's inspection.

Post World War I Activities

With the end of World War I greater attention was given to domestic issues. In 1919, legislative provision was made for extending the hours for inspection when necessary. The company requesting such service was to pay for this overtime.

Furthermore, the meat inspection coverage was extended to horse meat and horse meat products, all of which were to be labeled as "horse meat" or "horse meat product." Only four slaughtering plants were operating in the 1920-1923 period slaughtering only 5,071 horses. Later in the decade this number increased only to drastically fall in the 1930's and then to increase in the mid-forties, fall in the late 1950's, and increase again in 1973. The volume of meat inspection was generally increasing during the 1920's, but there were some reverses from year to year. Similarly the number of establishments involved came and went, with some firms going out of business or discontinuing Federal inspection in interstate commerce. In a few instances inspection was withdrawn because of noncompliance with regulations

Quantities of Meat Inspected for Selected Government Agencies

(Pounds)

Fiscal Year	Navy Department	Marine Corps	Army War Department	Veterans Bureau	Interior Department Bureau of Indian Affairs	Justice Department Federal Peniten-tiary	Federal Surplus Relief Corp. CCC(1944)
1909	3,288,163						
1910	6,648,072						
1911	11,112,060						
1912	9,688,427						
1913	12,120,678						
1914	15,565,952		93,067				
1915	12,808,056		87,982				
1916	14,016,818		86,874		217,535		
1917	24,017,321		26,352,305		619,961		
1918	81,793,418		234,751,245		173,416		
1919	173,463,509	9,931	119,074,506		540,226		
1920	47,958,718	273,096	4,053,970		17,080		
1921	74,492,585	414,058	3,377,953		413,058		
1922	68,179,403	3,503,021	1,399,490		305,560		
1923	46,721,492	3,989,554	812,279		459,699		
1924	49,294,340	3,656,224	526,604		366,617		
1925	53,217,397	3,563,065	802,104		483,166		
1926	43,959,843	3,502,669	576,932		534,594		
1927	61,818,870	2,802,013	201,537	289,119	536,700		
1928	48,794,825	1,989,780	313,494	1,205,929	582,825	1,254,411	
1929	45,276,256	2,331,850	773,106	2,947,483	648,368	2,499,455	
1930	45,676,484	2,509,147	1,054,054	3,376,892	769,113	2,830,634	
1931	47,659,461	2,264,673	1,084,175	3,691,024	757,716	3,254,388	
1932	49,236,579	2,549,401	1,073,881	4,124,068	713,610	3,161,410	
1933	50,268,392	2,442,818	861,490	4,833,645	993,406	2,581,488	
1934	33,459,592	2,672,026	648,721	4,323,848	558,552	3,190,516	
1935	47,583,890	2,698,111	502,403	5,104,299	990,906	2,644,634	
1936	48,797,369	2,344,830	501,206	8,035,552	1,253,299	3,190,516	
1937	56,339,741	3,093,089	58,730	6,359,767	1,040,317	3,083,823	
1938	60,778,997	2,880,997	586,169	6,411,715	968,693	3,211,707	
1939	66,143,181	3,654,609	474,054	7,198,590	1,129,407	3,552,713	
1940	81,540,244	4,615,967	492,190	7,476,472	1,078,343	3,886,314	44,455,237
1941	146,494,239	8,430,072	621,457	5,987,418	1,352,023	3,561,031	256,304,936
1942	347,678,698	15,466,547	668,468	6,228,052	927,428	3,073,282	13,300,824
1943	671,620,601	73,685,214	357,035	1,590,133	371,739	1,234,263	13,778,853
1944	494,766,679	823,376	279,224	620,825	8,083	122,168	292,123,169
1945	NA						
1946	NA						
1947	92,255,178	28,127	110,964	1,467,481	38,446	5,560	NA
1948	215,351,425	461,991	86,149	3,148,551	4,592	76,084	76,282,646
1949	219,607,657	12,204	94,489	3,824,310	3,473	157,297	36,293,255
1950	173,436,541	10,714	91,990	4,939,609	17,005	90,813	12,313,413
1951	264,700,052	97,076	76,937	3,701,504	7,591	98,205	1,137,650
1952	392,285,434	139,104	60,403	3,658,431	25,113	94,718	NA
1953	396,939,206	164,224		3,844,338		59,648	992,413

under the Meat Inspection Act. Peaks were reached for cattle in 1926 and 1927; for sheep in 1929; and for swine in 1924 and 1928. In part, adverse weather conditions in various sections had their impact on the early 1930's numbers of those slaughtered under the Federal inspection program with some ups and downs. In part, this was program related or market oriented.

Meat Inspection in the 1930's

The Meat Inspection Division was actively involved in the emergency programs and the agricultural adjustment programs of the 1930's. Special inspection was conducted for the Civilian Conservation Camps and the Federal Surplus Relief Corporation. In 1934 the Division supervised the killing of 221,113 "piggy sows" and 6,147,954 pigs under the Agricultural Adjustment Administration's hog reduction campaign. Approved meat was processed and delivered to various relief agencies. The remainder was made into inedible grease and tankage. The Bureau also supervised the handling and tanning of sheepskins and grading of hides of cattle and their storage, reinspection, and disposition. Inspections were made in connection with the cattle purchase program, and drought and flood relief programs under various schedules for the Federal Surplus Relief Administration. Meat was boned and canned, inspected or reinspected, rejected, or passed. Lard was also packed and shipped under supervision. The Bureau inspected pork and beef for the War Department for the Civilian Conservation Camps beginning in fiscal year 1934. In 1934, BAI, at the request of the Bureau of Indian Affairs, supervised the inspection and slaughter of 85,390 Navaho sheep under the sheep reduction program. The meat was distributed on the reservations.

Meat Inspection and World War II

During World War II, the Department sought to insure an adequate supply of food for the civilian population, an expanding military establishment, and our allies. Revised production goals were announced in February 1942 with emphasis on increased production of milk, eggs, hogs, cattle and calves, sheep, and chickens.

In June 1942 Congress authorized the Secretary to extend inspection to include all meat packing plants that were selling meat to Federal agencies. Some had not been subject to Federal inspection previously because their products did not move in interstate commerce. At that time, 659 places were involved and a year later this had increased to 842. In the course of the war period, plants had to set aside a certain percentage of their meat for Federal procurement. Moreover, they were required to have Federal licenses before they could slaughter any livestock.

In practice, this extended USDA grading and inspection activities to insure that meat purchased by the Federal Government was slaughtered and processed under sanitary conditions for a wholesome product meeting the established specifications. This applied only to meat purchased by the government with, no doubt, some spillover impact on the plants' other output. This interrelated system was continued throughout the war period.

Meat inspection activities were part of the shifting organizational maze of USDA. In December 1942, the enforcement of the Meat Inspection Act was transferred from the Agricultural Marketing Service to the Food Distribution Administration. On January 21, 1944, this became the Office of Distribution; on January 1, 1945, this Office was abolished and the meat inspection activities were transferred to the new Office of Marketing Service. On August 20 of the same year, the Production and Marketing Administration was established and the direction of meat inspection was returned to the Bureau of Animal Industry. This action, the chief reported, was in line with the original intention that when the emergency ended the function would be returned to BAI.

Following World War II, the processing industry changed significantly. The market for processed meat and poultry products ranged from sausages, cold cuts, partially cooked meats to frozen dinners, pizza, and pot pies, many composed of complex blends of ingredients. Costs of inspection increased rapidly as more inspectors were needed and more scientific analyses made.

User Fees

Even during the pressure of wartime activities, the question was raised of shifting the cost of meat inspection from the Federal treasury to industry. In the early postwar period, as the drive for economy in government increased, the question was raised again. A study of various inspection services urged that since industry was the recipient of inspection and benefitted from the service it should pay for it. Accordingly, Congress directed the imposition of the fees. The charges went into effect on July 1, 1947. Roughly nine months later, hearings were held on a bill that would

repeal the user fees. Packers, farm organizations, and farmers protested the fees.

However, the Chief of BAI had reported in the appropriation hearings that the program had operated smoothly. Nonetheless, Congress repealed the imposition of user fees effective July 1, 1948. In 1952, under authority of the annual appropriation act, the Bureau of Animal Industry issued regulations covering payment for meat and poultry inspection services that were requested by industry, in excess of those provided under regularly appropriated funds. In the 1980's several proposals were made to shift the cost of the inspection to industry. Again the question of the benefit to the consuming public has been used as justification for its continued support from the U.S. treasury. Even in the 1985 appropriation hearing, a member of the House Appropriation Committee said it was unlikely that such a proposal would be adopted.

Inspection of Pet Food

As time passed some of the meat that did not pass inspection, and meat not normally consumed by the public, was diverted into the growing industry of pet food. A more affluent economy contributed to a demand for the convenient processed food that became available in canned, semi-moist, frozen, and dry form. Voluntary inspection of canned animal food, under authority of the Research and Marketing Act, was announced on November 15, 1946. Industry was to request and pay for the service that would include supervision of sanitary conditions in plants processing the food and the steps of preparation.

The function was assigned to the Agricultural Research Service and followed meat inspection to Consumer and Marketing Service, Animal and Plant Health Inspection Service, and Food Safety and Inspection Service. Regulations for this activity have been published in the *Federal Register* and are part of the *Code of Federal Regulations (CFR)*. This has been generally a minor activity with little inspection performed over the last four decades.

Automation Comes to Meat Inspection

Hollerieth and other card punch devices had been used from the turn of the century for collecting data, at first, by the Weather Bureau and then by various other agencies. There were many changes in the equipment and its utilization. But in 1948, automation arrived to speed up meat inspection paper work. IBM equipment was used extensively for inspection reports. The Mark-Sence system was being used with the inspector making pencil entries on the cards that were read by the card punch system. In 1979, USDA adopted an Automated Import Information System that receives and stores each day's inspection results from all ports. On the basis of these, personnel can be reassigned to meet loads.

The Fiftieth Anniversary

In 1956, the Department celebrated 50 years of USDA meat inspection, although this had its roots in the 1890 legislation. An exhibit was opened by Secretary Benson in "the patio" of the USDA Administration Building on June 6, 1956. Subsequently, the exhibit was shown in various parts of the country at meetings and expositions. The Department pointed with pride that "in cooperation with the industry (it) has for 50 years given American homemakers assurance that meats available from meat retailers and food markets are clean and wholesome—and produced from healthy animals."

Erwin Peterson, Assistant Secretary for Federal-States Relations with general responsibility for meat inspection, proudly referred to the "Inspected and Passed" purple stamp that had for 50 years certified "that the meat so stamped has come from a healthy animal and measures up to high standards of wholesomeness and cleanliness." Veterinarians assisted by lay inspectors had been the mainstay of the system. By 1956 they were stationed in 1200 packing plants in 468 cities across the country. Secretary Peterson cited meat inspection as an important factor in the growth of the meat industry with economic benefits to the consumer, industry, and the farmer.

P. N. Jarvis, speaking for the meat industry, saluted the people in the meat inspection service who had assured the consumer of wholesome products, whose cooperative efforts had aided livestock producers, contributing to the value of agricultural products, particularly those producers who were willing to accept new ideas and processes.

However, this was a celebration of Federal meat inspection that covered meat processed for interstate commerce. There was also the whole subject of State and municipal inspection of meat.

Organization and Legislation

The post war period saw major reorganizations within the Department of Agriculture as well as other Federal agencies. The structure had become so complicated that the Hoover Commission on Organization of the Executive Branch was established in 1947. Its report on the reorganization of USDA in 1949 recommended that a regulatory service be established. Further it urged that all regulatory functions relating to food, including meat inspection, be transferred to USDA and those relating to other products be in a reorganized Drug Bureau. However, these changes were not made. B. T. Simms, Chief of the Bureau of Animal Industry objected to the transfer of this segment of work from his agency on the ground that it was interrelated with other activities of the Bureau.

Congressional consideration of making poultry inspection mandatory had raised the question of its organization and whether poultry inspection should be combined with meat inspection which had long been mandatory. As early as 1951, a Bureau of the Budget report had recommended "cross servicing" between meat inspection units of BAI and the poultry inspection in the Production and Marketing Administration. A task force report of the Hoover Commission recommended in 1955 that if poultry inspection were made mandatory, it be placed in the Agricultural Research Service instead of the Agricultural Marketing Service. A year later, a Senate report on the Food and Drug Administration recommended against the bill that would have placed mandatory poultry inspection in that agency. Instead, it recommended that it be in the Agricultural Research Service. The next month the Senate Agriculture Committee recommended that the Secretary decide where the proposed mandatory inspection be assigned. Early in 1957, another bill was under consideration; representatives of the poultry industry and the National Grange favored placing poultry inspection under AMS, while consumer groups, state food and drug and health officials, and the Farmers Union favored placing it in ARS. The bill as finally passed in 1957 left the decision to the Secretary. It remained in AMS.

Another development in the 1950's was the campaign for the enactment of the Humane Slaughter Act. Many packing houses opposed it, but consumer groups, the Society for Animal Protective Legislation, American Humane Association, and labor unions supported it. The Act, approved August 27, 1958, covered the humane handling and slaughtering of livestock. At that time its general implementation was voluntary. The law specified that the animals should be rendered insensible by a single blow, gunshot or electrical, chemical, or other rapid effective means before being shackled, hoisted, thrown, cast, or cut.

Under the Act, ritualistic slaughter by Jewish or other faiths that prescribed a method of slaughter were exempt from the provisions of the Humane Slaughter Act. Federal contract officers purchasing meat or meat products were required to purchase meat that had the humane slaughter stamp on it. In 1978, both the Humane Slaughter Act and the Wholesome Meat Act were amended. Essentially the Humane Slaughter Act was incorporated into the Meat Inspection Act specifying sections being changed. Thereafter, all meat inspected in the United States and imported meat was to come from animals that had been humanely slaughtered, making this mandatory instead of voluntary.

Improving Meat Inspection

Through the years Federal, State, and local meat inspection systems had developed individually and separately. The Federal system was primarily responsible for inspection of meat and meat products moving in international trade and for interstate shipments of meat and meat products. State and local authorities determined the scope of their coverage of meat and meat products consumed within their respective jurisdictions. Moreover, there was little control over rendering plants. Thus, some areas had no meat inspection, others had increasingly stringent regulations to the point where some systems were more inclusive than the Federal program.

For a number of years the discussion of the variations had increased with a call for some common standards. And these were the years when there was a period of increased Government concern for an adequate and safe diet for the consumer, and consumer groups had become more active in promoting protective legislation.

The Talmadge-Aiken Act of 1962 provided for cooperation between Federal and State agencies in regulating the marketing of agricultural products. The act was a piece of general legislation that authorized the Secretary of Agriculture to enter into broad cooperative agreements with State departments of agriculture. Few States took advantage of its application to meat inspection until after the Wholesome Meat Act was enacted in 1967. By 1971, the States were required to have an "equal to" system in place. The question continued in limbo.

The House of Representatives conference report, May 26, 1958, on the 1959 Departmental appropriation recom-

mended that the poultry inspection work be placed in the Agricultural Marketing Service. Further "the Secretary should give attention to set up a new combined inspection service or should take such other steps as may be necessary to prevent the creation of duplicate offices and supervisory personnel. . . ."

Therefore, on October 17, 1958, Secretary Benson appointed a study group to review the meat and poultry inpection work. Members and representatives visited field installations and typical plants to observe program activities.

The new program represented a shift from voluntary inspection of poultry conducted at the request of, and paid for by, industry to mandatory inspection provided without cost to industry. Work load increased from 320 poultry processing plants in 1957 to 960 plants in January 1959, and the expenditures doubled.

The study group made its report to the Secretary on January 9, 1959, recommending that the two programs remain organizationally separate—meat inspection in ARS and poultry inspection in AMS. Retaining poultry inspection in AMS, it considered a wise decision to promote transition from a voluntary to a mandatory program and in line with the views of industry. On the other hand, meat inspection had had a long history of development of over 60 years in a scientific organization.

It found distinct differences between the two systems. Meat inspection was rendered primarily in cities and poultry inspection in rural areas.

Concentrations of poultry activities were in an area east of Nebraska, especially in six southern states, Pennsylvania, the Delmarva penninsula, and New England. Meat inspection was concentrated in the Eastern United States and in the upper midwest. The group did not perceive that there could be absorption of local work by the present organizational units. Looking at the overall picture, it did not recommend changes in organizational structure at that time, but recognized that future developments might indicate the necessity for such action. Actually, the only feasible suggestion for improved direction that the committee made was for joint operation of laboratory facilities and centralized common functions. It further endorsed the cross utilization of personnel to avoid duplication and transfer of funds between the respective services.

At this time the work in USDA was facing the problems that it has faced at many times in its history—the squeeze between costs and the adequacy of staff as work increased in volume. In 1958, a Congressman reported that the meat inspection appropriation had increased from $14,160,000 in 1953 to a recommended $19,200,184 in 1959. The number of employees would grow from 3,171 to 3,263. The average cost per man-year would change from $4,461 to $6,001. Meanwhile, the number of livestock inspected had increased from 92,590,737 to an estimated 104,000,000 in 1959. The number of inspected plants had grown from 922 to 1,306 and the number of cities and towns having inspected plants increased from 490 to 520. Thus, the workload and inflation more than offset the increased appropriations.

As early as 1961, bills were introduced in the United States Congress to increase the coverage of the meat inspection act and to permit cooperation with State meat inspection services.

On March 15, 1962, President John F. Kennedy delivered a special message to Congress on protecting consumer interests. In this he spoke of many outmoded laws and the need for new legislation. The consumer had a "right to safety—to be protected against the marketing of goods which are hazardous to health or life." He spoke of the request for increased appropriations for meat and poultry inspection and of the need to broaden the coverage of the meat inspection act beyond meat in interstate trade.

In July 1962, the House Appropriations Committee asked the Department to make a special study of the extent to which it could certify State meat inspection systems and license them to inspect meat moving in interstate commerce. The Agricultural Research Service early in 1963 reported that a survey was made of State meat inspection legislation that revealed a wide variation in coverage from no provision to a well planned program.

Thirty four States had laws providing for some type of meat inspection and 31 of these actually were conducting some kind of meat inspection. U.S. inspectors, with the cooperation of State officials, visited slaughterhouses and meat processing plants, finding great differences in sanitary and operating conditions. There were some with good sanitary conditions operating safely for the public health. However, there were contamination, unsafe chemical additives used, false labels, improper cleaning methods, and failure to detect or control dangerous parasites, such as

trichinae. Even in Federally inspected plants there were some problems.

Legislation in 1962 authorized the Department to cooperate with States in enforcing certain Federal laws, including meat inspection. A task force was appointed to consider cooperative work. The Department was already providing technical counsel, at the request of the States, to improve their meat inspection services. Also, most of the States designated collaborators to be appointed by the Secretary of Agriculture, who were to work with the Meat Inspection Division.

Bills were introduced in both House and Senate in 1963 to strengthen the 1906 act by eliminating some of the exemptions and increasing the cooperation with the States. Late the following year, the Department proposed an amendment to the inspection regulations to provide for cooperative State-Federal administration and enforcement of Federal regulations. Cooperating States would conduct inspection service under the general supervision of ARS. Then products that passed such inspection would be eligible for interstate shipment or for export. Authority for such agreements was delegated to USDA by the Talmadge-Aiken Act of 1962.

According to the Administrative Assistant Secretary, the Department had made a commitment to both the Senate and House Appropriation Committees in 1964 to reach a decision on combining the meat and poultry inspection activities. The Department again was considering making them self-financing by charging fees to packers and processors.

One of the early changes was the transfer of meat inspection work from ARS to the new Consumer and Marketing Service (CMS) by a Secretary's Memorandum, effective February 8, 1965.

Soon after, March 1965, the Secretary appointed a task force, composed of top level personnel, to review the meat and poultry inspection services. The group was to study and recommend procedural changes and legislative revision to strengthen the food inspection services and consumer protection.

A series of four Federal-State regional collaborator conferences were held in March and April 1965 to identify sources of unwholesome meat to keep it out of consumer channels. Its suggestions were made available to those studying the inspection activities. The special task force completed its review of legislation on meat inspection and made a list of suggested changes to strengthen USDA's authority for more adequate control. This report was circulated for suggestions. In October the Secretary announced that he was asking Congress for the first major overhaul of the 1906 Meat Inspection Act.

When Secretary Freeman announced his request to Congress for a major overhaul of the Meat inspection work in October 1965, he also discussed changes that were being made under the direction of the task force that he had appointed earlier that year. Field offices of the service had been consolidated from nearly 100 to about 40 and the work was transferred from ARS to the Consumer and Marketing Services. The Department was assisting States in developing or improving their programs. The review of foreign meat inspection was leading to a stronger program. A number of operating procedures were tightened, including those for meat entering official establishments for further processing, handling of boneless meat by refrigerated warehouses, transportation of rendered fats between establishments under Federal inspection by tank cars and trucks and increased unannounced supervisory and spot checks of meat inspection and labelling requirements.

President Johnson, in his first budget message to Congress on January 20, 1964, placed emphasis on economy in government and a strong economy. As part of this, he indicated that users should pay for services received. The Bureau of the Budget, in its annual budget for USDA, provided for the imposition of user fees for meat inspection services. Opposition members of Congress asked the President to withdraw the proposal and it was not enacted.

Johnson again brought up the question in his 1965 budget message. Again it was attacked in the press and in Congress. Among the points stressed was that this was a health measure to protect consumers in a time when increasing attention was given to them. The public benefitted and therefore, it should be financed by the Treasury. In December 1965, the Department did increase the charge that it made for overtime inspection of meat because of increased operating costs.

A follow-up on organizational changes led to the transfer of responsibility for investigating meat and poultry violations to the Office of the Inspector General. In addition, Technical Services, Processed Meat Inspection, and Livestock

Slaughter Divisions— reporting to the Deputy Administrator of CMS for Consumer Protection— were established in 1966.

In February 1966, at the request of the Johnson administration, a proposal for a strengthened meat inspection act was introduced in the United States Senate: it was opposed by the major meat, livestock, and farm organizations, that mounted a campaign against its approval. And again the proposed changes died.

By the Spring of 1966, meat inspection work throughout the nation was administered by seven field district offices, each with two deputies to coordinate slaughter and processing inspections. Officers were placed in charge of circuits, they directed supervision over the inspection in packing and processing plants in their circuits.

Meanwhile, modern technology was complicating the inspection procedures as the lines moved faster. Few States had competent personnel to meet the pace. USDA personnel and industry sought to meet the greater pressure.

Once again in his 1967 consumer message President Johnson urged that the 1906 Meat Inspection Act be amended to provide greater protection to consumers and Federal assistance to States in developing their State inspection programs.

The campaign again gained speed. As the legislation progressed through the halls of Congress some opposed the extension of Federal authority as an invasion of "States rights." One State commissioner of agriculture referred to the "real ulterior motive (as) complete federalization of meat inspection (because they) have panicked at the idea of States setting up adequate meat inspection programs." There were charges that USDA was masterminding this extension of its authority. A number of packing and processing representatives joined others from some State departments of agriculture in opposition.

Rodney Leonard, Deputy Assistant Secretary of Agriculture, summed up the Department's support of the pending legislation when he testified before the House Agriculture Committee on June 26, 1967. It would authorize cooperative arrangements with the States to develop effective State meat inspection programs; provide enforcement tools not previously authorized; broaden authority over meat products of use as human food; and clarify codification and consolidate several statutes into one.

The Wholesome Meat Act

On December 15, 1967, President Johnson had a number of members of Congress, representatives of the Department of Agriculture, Upton Sinclair, and others to witness the ceremonial signing of the Wholesome Meat Act, a landmark event in consumer protection. The President paid special tribute to Sinclair's contribution in giving added impetus in *The Jungle* to the passage of the 1906 Meat Inspection Act. But a big gap had existed in the system in that nonfederally inspected meat was sometimes not too different in the 1960's from that described in Sinclair's book. In the President's thoughts, "This bill really crowns the crusade that you, yourself (Sinclair), began some 60 years ago." The Secretary of Agriculture was to recruit the inspectors needed to implement the Act. The Wholesome Meat Act of 1967 was passed to encourage uniformity in the meat inspection system and coordinate and close loopholes in the various phases of the program. More extensive review for equivalency with or at least "equal to," the U.S. system was required under the new legislation. Annual reports to Congress on operations and effectiveness of the meat inspection system were required. Under the act, the Federal Government would pay up to 50 percent of the cost of State inspection under cooperative agreements. At the time the Act was passed, nine states had no meat inspection legislation at all. Only 25 States had mandatory inspection of processed meat products.

The Secretary of Agriculture had indicated as the two main goals of meat inspection the protection of the wholesomeness and truthful labelling of the nation's meat supply and the improvement of the inspection process by the development of new techniques to meet changing conditions in the meat industry.

Even after the Act had been approved there was still opposition to it, with some members of Congress, industry representatives, and some State officials urging its repeal. Nonetheless, States and USDA were working together to implement the act. The trade also cooperated in publicizing the Act. The American Meat Institute (AMI) sponsored eleven regional conferences on the implementation of the Act and on the way those outside the Federal system could adjust to the requirements of the new law. Officials of AMI had the cooperation of USDA's Consumer and Marketing Service and

officials of 41 of the 48 continental states. In addition, the USDA was carrying out its own program of meetings of the Federal Meat Inspection Directors with their State counterparts, that might be in State Departments of Agriculture or Public Health in late 1967 and early 1968.

President Lyndon Johnson and Upton Sinclair, author of *The Jungle,* at the signing of the Wholesome Meat Act, December 15, 1967.

Advisory Committee on Meat and Poultry Inspection

On March 20, 1968, the Secretary, in accordance with the Wholesome Meat Act, appointed the National Meat Inspection Advisory Committee to evaluate State programs, obtain better coordination between Federal and State programs, and provide adequate protection for consumers. It was composed of 17 State officials concerned with or responsible for programs under the Act. At this time, the intent to also invite State technical and operational meat and poultry inspection representatives was announced. The Assistant Secretary for Marketing and Consumer Services was to serve as chairman, and the Deputy Administrator of CMS for Consumer Protection was to serve as executive secretary.

Following the passage of the Wholesome Poultry Act, the name of the committee was changed on October 28, 1968, to the National Food Inspection Advisory Committee. On November 17, 1970, it was reestablished as the National Meat and Poultry Inspection Advisory Committee. The name was again changed on August 2, 1973, to Advisory Committee on Meat and Poultry Inspection. Membership from USDA was changed to include the Administrator of Animal and Plant Health Inspection Service or his designee as vice-chairman and a representative to serve as executive secretary. Similarly in 1978, another Secretary's Memorandum was issued designating the Assistant Secretary, Food and Consumer Services as Chairperson, and a representative of Food Safety and Quality Service (FSQS) as executive secretary.

Organization for Implementation

Following the passage of the new regulatory legislation, organizational changes were made in the Washington office. A single division was created to deal with operations; laboratories were upgraded to division status; other support functions were combined in a Standards and Services Division; and compliance and internal review functions were brought together in a division.

A single official at the State level was to have responsibility for Federal activities and for cooperation with State officials. Thirty-four area offices were established primarily at State capitals to supervise meat and poultry inspection in the field. These were to report to the respective 8 regional offices. As another step in strenghthening the meat inspection work, a deputy administrator of the Consumer and Marketing Service was appointed in charge of this pro-

gram. The reorganization of the work was announced by the Secretary of Agriculture on November 17, 1970—an outgrowth of the May-Barnard report. Philip J. May from Michigan State University and Alfred Barnard, in charge of regulatory compliance in the food and drug administration, had been asked to study the organization of the meat inspection work in April 1970. A number of their other recommendations, however, were not adopted. A year later, the eight regional offices were reorganized into five; area offices were established; and 117 circuit offices were closed. Circuit supervisors, reporting to the area offices were responsible for reviewing State inspected plants.

When James K. Payne, an Assistant to the Deputy Administrator of CMS, reviewed four years of operation of the cooperative State meat inspection work in 1971, he reported that much progress had been made. All States had mandatory authority and some States had upgraded existing laws. They had signed cooperative agreements with USDA, some with supplemental agreements providing for cross utilization of Departmental and State personnel on State programs and Federal inspection activities within the State. He was optimistic about the future of State meat inspection programs.

On the other hand, Senator John Melcher discussed the inadequacy of the imported meat program and its lack of comparability with the domestic program. At about the same time Kenneth McEnroe, who was in charge of meat and poultry inspection, described the growth as "staggering," attributing it to changes in the industry and plants. More sophisticated techniques were being used to minimize variations in product quality. His third area of growth was prompted by increased consumer interest. Moreover, the foreign program required by the 1967 legislation placed an added burden.

During much of the seven years that the meat inspection work was in the Consumer and Marketing Service, there was an undercurrent of opposition to the operation, the program, and the repeated suggestion that it be placed in a separate agency. This opposition frequently surfaced in the annual appropriation hearings and the press. Harrison Welford, in *Sowing the Wind* in 1972, also described the inadequacy of the administration of the Wholesome Meat Act by the Department and more specifically by the Consumer and Marketing Service.

Finally, on April 2, 1972, the meat inspection work was combined with the plant and animal inspection activities in the new Animal and Plant Health Inspection Service with continuing internal changes in organization. A deputy administrator was appointed to supervise the meat and poultry inspection work, but this only continued for less than five years. Then as part of a realignment of activities, the Marketing and Consumer Services grouping under an Assistant Secretary was split into two groups—one for marketing and one for consumer services. Meat inspection functions and certain grading and standardization services were combined on March 14, 1977, in the Food Safety and Quality Service. This and the Food and Nutrition Service reported to the Assistant Secretary for Food and Consumer Services. A proposed plan for reorganization of the new agency was under consideration in 1978; in this plan the meat inspection program would have lost its separate identity. Sufficient opposition prevented its implementation.

In January of the next year, a task force on meat and poultry inspection was appointed by the Secretary of Agriculture, including representatives from FSQS and the National Association of State Departments of Agriculture. This was to determine means of reducing the costs of the Federal and State inspection programs. As a result of its recommendations, a $4.3 million saving was made in cost avoidance in State programs in fiscal year 1980.

Again change was in the air. In 1981, commodity services functions of FSQS were transferred back to Agricultural Marketing Service and FSQS became FSIS, Food Safety and Inspection Service. With the departure of the grades and standards work, in effect, meat inspection had its separate existence without the function being highlighted. Such changes in organization as well as changes in procedures or regulations were published in the *Federal Register*.

A review and evaluation staff was established within FSIS. On a continuing program they visit locations throughout the country to make basic reviews observing products, inspection methods, slaughter and processing procedures, product environment and records. These are supplemented by special reviews and evaluations of specific problems, inspection or processing techniques, or management concern.

Staffing standards were also revised in July 1981 to improve productivity, resulting in the elimination of 40 positions and the transfer of the inspectors to other plants. Other procedures in swine inspections were expected to eliminate more than 100 additional jobs. Work was under way also to improve procedures in poultry inspection.

Over the years, many factors were creating what seemed to some to be a seething cauldron that would boil over. One of these, the Center for Study of Responsive Law (Ralph Nader) published *Return to the Jungle* in early 1983. Playing on the title of Upton Sinclair's famous book, *The Jungle*, Kathleen Hughes described how she believed the

present administration was emasculating the meat inspection work. The report drew on interviews with civil service inspectors and some supervisory personnel. These painted a bleak picture of many aspects of the meat inspection program and of the end product that went into trade channels. FSIS prepared a 25 page rebuttal to the questions raised.

In November 1983, FSIS asked the National Research Council to make a study of the scientific basis of its inspection program for meat, poultry, and meat and poultry products. The investigating committee was composed of representatives from veterinary schools, animal science and health schools of major universities, U.S. Public Health Service Center for Disease Control, and other health service agencies. The report was published in 1985 and was generally favorable.

However, the agency, between the time that the study was begun and its completion, was faced with the disclosure of a long history of violations of the Meat Inspection Act by Cattle King Packing Company and by Weyandt and Sons Wholesale Meats. Considerable legal action ensued. FSIS asked Congress to provide it with additional authority to enforce the system, especially more leeway to withdraw or withhold inspection services for infractions. At this time, some members of Congress stated that there was already sufficient authority to enforce the law.

Laboratories

The laboratories began tests for DDT in about 1951 and the pesticide residue program was begun. Since 1968 they have been doing drug residue analysis. In 1973, an interagency agreement for cooperation in drug residue analysis was signed.

The seven meat inspection laboratories, located in different parts of the country, have through the years provided scientific support for the inspecting staff. The staff have referred samples of meat that were "suspect" under the meat inspection regulations. From time to time the problems change. At one time many of the samples checked and not passed showed excess water or fat in sausage and ham or included substances not permitted under regulations. In 1931, when increased attention was given to inspection of imported meat, more than a quarter of the samples sent to the laboratories were rejected. However, this declined to about ten percent. They have also examined meat purchased by government agencies to determine its meeting specifications set. Samples of water used in processing meat and related activities were tested for purity. Adverse reports were discussed with the respective establishments and most were promptly corrected.

The Federal laboratories were supplemented by State laboratories and private laboratories certified to conduct tests at the expense of the plants.

Other laboratories are giving more attention to microbiology. Product safety and quality raised the question of basic responsibility and government monitoring. Supporting staffs have become increasingly diverse including veterinarians, engineers, food technologists, chemists, micro-biologists, sanitation specialists, and others working together to enable the inspection program to meet its responsibility for consumer protection.

Compliance Program

The Compliance and Analysis Staff was established in 1966 to better meet the need for regular and continued surveillance of the meat and poultry industries outside of the Federally inspected plants. Previously there had been meat law investigators and separate poultry regulatory investigators. This staff was reinforced when the Wholesome Meat Act was passed in 1967 and the Poultry Act in 1968 and the regulatory functions extended to meat and poultry and related products. In the early 1970's, plant review responsibilities were added to the work of the staff.

The program was designed to strengthen management controls and regulatory and enforcement features of the meat and poultry acts and other related legislation. On the basis of the staff's location of problems, recommendations would be made to the appropriate office for corrective action. Moreover, a major duty of the Compliance Program is to keep the Administrator advised at all times of real or potential problem spots. As it has done this, it has cooperated closely with the meat and poultry inspection staff.

Compliance officers, who are located at various places throughout the United States, regularly conduct reviews of meat and poultry dealers, transporters, and warehouses throughout the chain of distribution of our meat and poultry food supply. Their activities result in the detention of approximately 10,000,000 pounds a year of meat and poultry

believed to be adulterated or misbranded. These products must be brought into compliance before being used in food channels or otherwise destroyed.

National Residue Program

During the World War II years two lines of development were to have an incipient effect upon meat inspection in the post war years. Although DDT had been developed in Europe before World War II, it had not been available in the United States. During World War II and the early postwar period, DDT was used to kill insects and vectors of diseases affecting military and civilian populations. Subsequently, it was shifted to control of insects, parasites, and the like affecting plants and animals. This brought in the whole new type of organic pesticides that could be more effectively utilized than the older inorganic types. However, by 1951, there was a growing concern about their impact on humans consuming meat from animals who had been treated with the pesticide. The Federal laboratories began laboratory tests and the pesticide residue program developed.

The other developments coming out of World War II were the use of penicillin, sulfa, and subsequently derivative antibiotics and growth promotants. The discovery of synthetic penicillin in 1959 facilitated wider and more controlled use of the new drugs. Their use in poultry production facilitated large scale confined operations. Use with livestock enabled producers and feeders to increase animal size and insure healthier animals. However, this was taking place when greater attention was being given to consumer concerns and the possible effects of these drugs on the consuming public. The Wholesome Meat Act of 1967 and the Wholesome Poultry Act of 1968 both had protection of the consumer as a goal. Since 1968, the Department's laboratories have been doing drug analysis to determine the existence of residues. The National Residue Program is the government's way of determining the presence of chemicals of concern to public health.

The residue control effort has been divided into the National Residue Monitoring Program and the Surveillance Program. Under the Monitoring Program samples are selected by an automated scheduling process for examination by the laboratories. The Surveillance Program was designed to control the movement of animals (carcasses and parts) from places where violations had previously occurred, into the food chain, only after they are cleared. Other agencies involved include FDA, EPA, Cooperative Extension Service, and State offices. Following the 1983 reports of EDB (ethylene dibromide) in food, FSIS in cooperation with other agencies developed a laboratory testing system for meat and poultry. As a result of the tests, consumers were assured that the meat and poultry supply was safe and thus prevented disruption in the two industries. Now testing for EDB has been incorporated into the program for residue monitoring.

The program depends upon the cooperation of the Food and Drug Administration, the Environmental Protection Agency, the Food Safety and Inspection Service, the Animal and Plant Health Inspection Service, the Federal Extension Service, and the Agricultural Research Service. They have cooperated in identifying the presence of residues and methods of preventing such buildups to protect and promote producers' interests and insure food safety and quality for the consuming public. In 1973, an interagency agreement for cooperation in drug residue analysis was signed.

The total Residue Avoidance Program was instituted in 1982 as an educational program to assist farmers in identifying ways in which chemical contamination can occur and of preventing such buildups. But there continue to be challenges to be met.

In its report in 1985, on the meat and poultry inspection activities, the National Research Council reported that the residue program was not demonstrably adequate. Therefore, it urged that the residue listing facilities be expanded to make them more effective. Another program somewhat related is the proposed Hazardous Analysis Critical Control Points, considered for some operations. It is concerned primarily with criteria affecting public health that some feel should be applied comprehensively and rapidly.

Meat Inspection in a Nuclear Age

Army and Air Force veterinarians cooperated in providing instruction to inspectors and laboratory training on the effect of nuclear radiation on food animals and products. Supervisory inspectors received this training early in 1951. In 1954 and 1955, a staff member participated in several tests in the Nevada desert when atomic bombs were detonated above and below ground. Then from 1959 to 1962, meat inspection laboratories tested beef from several areas for strontium 90.

Cross-Utilization of Personnel

One of the cooperative areas was in the cross-utilization of personnel in developing the State-Federal operations under the Talmadge-Aiken and the Wholesome Meat Acts. By March 1971, instructions had been issued for such use of employees under a reimbursement procedure that would permit the use of Federal inspectors to supervise State inspectors in Federally inspected plants. However, when questions were raised about State employees supervising Federal employees when the Booz, Allen, and Hamilton study was in progress in 1977, they determined that such a practice was not appropriate. Nonetheless, as circumstances required, AMS and FSIS had memoranda of understanding in 1982 for such cross-utilization of personnel on grading and meat inspection.

Quality Control

By the 1960's, some processors were designing quality control systems. Partial voluntary quality control systems covering such manufacturing processes as net weight control and fat and water content were approved by USDA beginning in 1967.

In the early 1970's, the Department was directed to have a consulting firm prepare a plan for a lower cost inspection program. The Booz-Allen and Hamilton report of 1977 recommended that a "quality control" program be adopted for meat and poultry processing in place of the continuous inspection. In 1978, a report by USDA also endorsed an experimental quality control program. In 1980, USDA formalized its total quality control program, but it was still on a voluntary basis.

In 1981, quality control systems had been expanded to include all processing operations of plants that volunteered for total quality control (TQC). An economic incentive for adopting the system is the potential for reducing industry paid charges for overtime inspection. Special training programs have been established for USDA veterinarians and inspectors, representatives from the states, and some from the private sector. Basic to the successful operation of the system has been its dependency on selection or approval of participating processors who have maintained a historical compliance record of operation under the continuous inspection system.

A company voluntarily applies to USDA for participation in the program, outlining its quality control system, agreeing to make data generated available to inspection personnel and authorizing quality control personnel to stop production or shipment of goods if necessary. USDA evaluates the plant's operation including a review of the plant's facilities to determine their adequacy for an effective quality control program. Federal inspectors in approved plants monitor the system, using generated data to supplement inspection. They check only crucial "control points" such as ingredients and freezer temperatures and production stages and make less frequent unannounced inspections of the processing operations. Then companies under the system can use a special symbol on their package labels and advertisements to indicate that the processing plant operates under the program.

Reactions to this approach to inspecting processed meat and poultry have been varied. Industry has generally favored it. USDA has been able to spread its inspection force to cover more operations. Some consumer groups have found many flaws in it. A number of veterinarians and inspectors have felt that this approach did not insure adequate protection. As the program operated, adverse action has been taken against some processors. Finally, industry, agricultural, and the general press have discussed it.

The program has steadily grown. It is estimated that 587 systems will be approved and 530 systems operating under quality control in 1985; 3,946 systems have been approved and are operating under partial quality controls.

Product Labeling

The Department also, under the Wholesome Meat and Poultry Inspection Acts, by 1974, developed new regulations on product labeling. All labeling is approved prior to use. Some processing plants have an in-plant quality control program; products to be cooked after purchase must declare the nutrition information on an as prepared basis with cooking instructions included. Other features of the labeling inspection include percentage specifications, labeling for vegetable protein, and open dating.

Selected Changes in Inspection

The takeover of State meat and poultry inspection programs has increased the workload and requires more USDA personnel. This can be critical at a time of budgetary constraints. Changing techniques in meat processing have meant changes in inspection procedures. The adoption of partial defatting and mechanical deboning processes have required new standards for protein quality. Greater attention has been placed on "hands off" inspection in poultry. New equipment has been tested to improve inspection procedures.

In 1979 the Department began using a rapid test on the premises (STOP) to detect antibiotic residues in dairy cattle. Three years later it proposed expanding its application to a number of other animals as well as poultry.

Similarly new procedures were inaugurated in 1981 in swine inspections, utilizing mirrors, speeding up the process and cutting personnel required. In February, 1984, FSIS instituted an Intensified Regulatory Enforcement (IRE) program for plants that consistently fail to meet satisfactory operating standards.

POULTRY INSPECTION

Poultry was a minor commercial product in the early years of this century and continued to be so for many years. Consumers bought live poultry direct from the farmer-producer or from a produce house or else selected a New York dressed bird with only the blood and feathers removed. It was up to the housewife to clean and prepare her chicken for cooking.

In the early 1920's a large traffic developed in live poultry to distant distribution points. Special railroad cars, sometimes called "Palace" cars were constructed for the trade.

An outbreak of fowl plague occurred in the New York Central Railroad yards in New York City in 1924. Thereupon, a live poultry examination program was organized by the New York Live Poultry Commission Association. On November 15, 1926, USDA signed an agreement with this Commission and the Greater New York Live Poultry Chamber of Commerce taking over the earlier programs. Two years later the agreement was amended to include the inspection of dressed poultry and products for condition and wholesomeness. Similar agreements were signed with other cities. Then cities passed ordinances requiring processors to have their goods inspected under the USDA program. The program was referred to as a voluntary one since there was no Federal law requiring it.

World War II had its effect on the poultry industry. There were price controls for poultry but it was not rationed. Therefore, many consumers viewed poultry as a substitute for meat, creating an increased demand. Coupled with this was a similar growth in the demand by the military establishment to feed the expanding armed forces. New plants were built.

Military specifications required that poultry being purchased be inspected by either its Veterinary Corps or by USDA inspectors. In practice, most of the military purchases were dressed poultry which had acceptance inspection at the delivery point.

During the 1940's changes in the poultry industry were to make sweeping alterations. In the early years poultry was usually slaughtered in one plant and eviscerated in another. However, the war years and those following experienced a movement to combine the operations in one plant. Nonetheless, until the late 1940's there were only about 150 federally inspected poultry plants. Then the number quickly doubled. In 1949 a complete revision of the poultry inspection and grading regulations was issued to improve procedures and consolidate earlier rules for inspection and grading.

New directions in poultry production enabled rapid expansion. An important change with many ramifications was the confinement of the birds. In the controlled environment, scientific advances could be applied; new breeds of poultry were developed; and a seasonal market was expanded throughout the year. Broilers and frying chickens took over more of the demand.

In the mid 1950's Federal poultry inspection increased rapidly. During the first six months of 1956 the poundage of poultry bearing the "inspected for wholesomeness" label increased 53 percent above the same period of the previous year.

With expansion came more problems and there was marked increase in the demand for a mandatory Federal inspec-

tion program. A number of bills were introduced in the 84th Congress and hearings were held. These highlighted the importance of sanitary production for wholesome food and satisfied consumers.

In 1956 an outbreak of psitticosis was reported in Oregon with some illness in Michigan from people eating diseased poultry. Further hearings were held by both House and Senate committees on proposed Federal poultry inspection legislation. The Poultry Products Inspection Act became law on August 28, 1957. It provided for mandatory inspection of sanitation and processing activities, for antemortem and postmortem inspection of slaughtered poultry moving in interstate and foreign commerce, for labelling, checking, and inspection of imported poultry products. Responsibility for administering the program was assigned to the Agricultural Marketing Service. However, its operation revealed loopholes that called for new legislation.

The Wholesome Poultry Act, approved August 18, 1968, authorized the Secretary of Agriculture to determine the extent of antemortem inspection for poultry. In many ways it was similar to the Wholesome Meat Act of the previous year. It provided for Federal-State cooperation and also for "at least equal to" inspection for plants involved in interstate commerce. Since it was a mandatory program, industry no longer paid for the service.

The administration of the poultry inspection program continued its separateness in the Poultry Division of the Agricultural Marketing Service and the Consumer and Marketing Service. Not until late in 1968 were the meat and poultry inspection systems merged, although it had been announced in June of that year.

When Animal and Plant Health Inspection Service was established in 1972, plant protection and animal disease control and eradication were combined with meat and poultry inspection in one agency—a partial solution to the agitation for a special agency for inspection activities. Five years later the inspection activities were transferred to the newly established Food Safety and Quality Service and in 1981 the agency was reorganized as the Food Safety and Inspection Service.

Antemortem inspection of poultry took the inspection to the flocks or lots to check for condition of the birds. They were also examined in coops or batteries before or after being moved from trucks. Postmortem inspection is followed by processing inspection.

Per capita poultry consumption has continued to increase since the enactment of the Wholesome Poultry Act of 1968 (Figure 1). Since its peak in 1976 beef consumption has declined. Consumption of fish has increased in spite of its dramatic price increase (Figure 2).

Accordingly poultry and broiler production had constantly increased. As this occurred there were many discussions of ways to continue to insure consumers a wholesome product at the same time that the industry expanded, and pressure was exerted on USDA to improve and speed up its service. On October 29, 1984, a New Line Speed System (NELS), was established to speed up poultry inspection from 70 birds to 91 birds per minute. Plants using it were expected to have a quality control program. The new system was attacked by inspectors and others as not providing enough consumer protection. Another approach was to use a selected sampling procedure. Although FSIS had suggested it, the 1985 National Research Council report recommended against it. Instead, it sought to strengthen the program by tracing condemned carcasses back to the original owners.

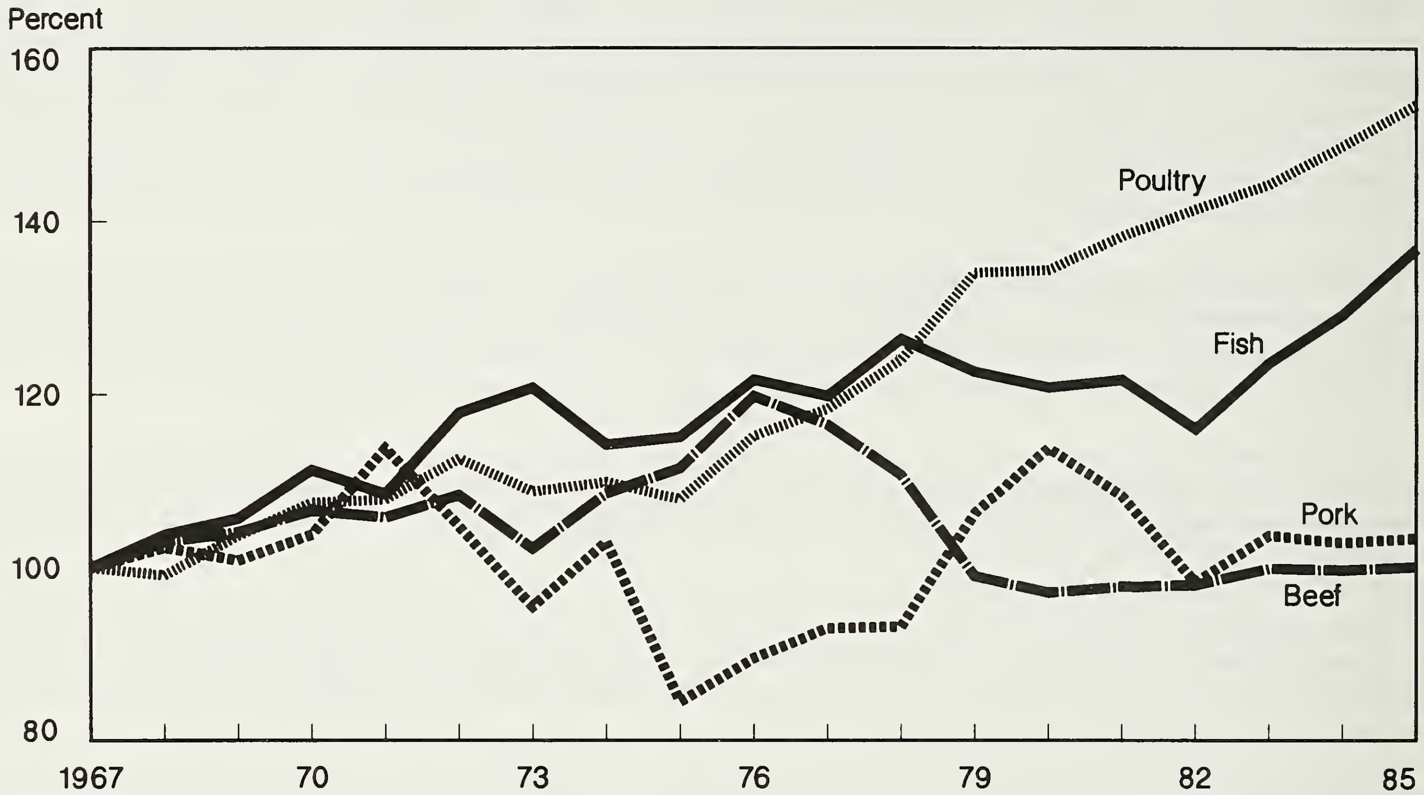
As the poultry industry has expanded, the use of pesticides, growth promotants, antibiotics, etc. also are being used to increase agricultural production. Laboratory monitoring of poultry for residues from these was undertaken on a statistical sampling basis. In 1976, about 8 million broilers were destroyed in one instance because of excessive dieldrin residue from industrial grade oil used in the feed supply of a number of growers in the same area. Another change in poultry inspection came with the amendment of the Poultry Products Inspection Act on June 30, 1982. This increased the number of turkeys that could be slaughtered and processed without inspection—somewhat relieving the pressure for inspecting personnel.

REPORTS

Over the years a number of investigations have been made into the operation of the meat inspection work from various angles.

Figure 1

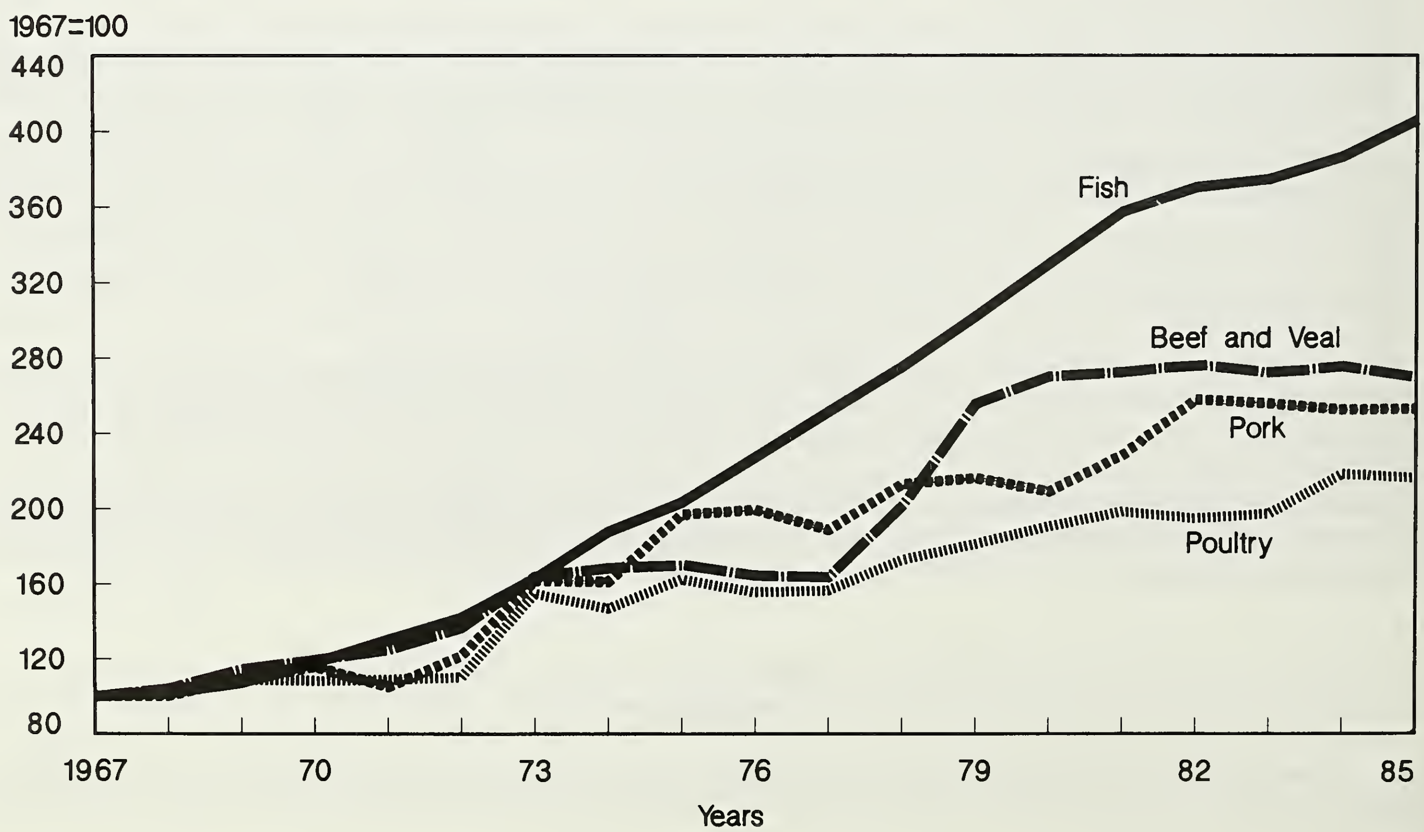
Quantities of Selected Items as a Percent of 1967



Based on a per capita consumption.

Figure 2

Consumer Price Indexes for Beef, Pork, Poultry, and Fish



General Accounting Office

An increasing number of these investigations have been made by the General Accounting Office, following the expansion of its functions in 1950 to include organization and management studies.

A report in 1963, when the meat inspection work was under the Agricultural Research Service, described conditions in State and Federal meat inspection systems. It found many fine nonfederally inspected plants and others where conditions were quite the reverse.

A period ensued in which a number of recommendations were made for strengthening the meat inspection work by expanding the coverage of inspection activities to include meat for intrastate commerce, and the requirement that State inspection programs be "equal to" the Federal program within two years.

The Consumer and Marketing Service, starting in July 1967, made a field investigation of nonfederal plants that soon evoked considerable criticism from Congress and then from the General Accounting Office in a report filed in 1968. Many parts of the report were given to the House Committee on Agriculture and were included in House Report 653, September 21, 1967, as examples of existing conditions in nonfederal plants. Certain State officials objected and CMS asked the Office of the Inspector General about the validity of the reports. This Office found that some of the observations were based on visits made to plants before the survey was begun.

In its September 1969 report, the General Accounting Office (GAO) was critical of the implementation of the Wholesome Poultry Inspection Act. It reported that CMS needed to strengthen its enforcement of minimum sanitary standards. Plants in repeated violation of standards were producing adulterated food unfit for human consumption. Failure to terminate services, GAO reported, may have implied that violations would be treated with minimum consequences. It was also critical of the practice of excessive water in poultry that increased the cost to the consumer. The Consumer and Marketing Service reported that it was taking remedial action in the phases of the poultry inspection criticized. But GAO investigators continued to have reservations about the effectiveness of the CMS enforcement. It reviewed reports in CMS Washington and area offices, of supervisory personnel in 40 plants in repeated violation of standards for sanitation facilities or equipment.

Again in 1970, GAO found laxity and unevenness in the application of inspection services in reinspected plants. The Administrator of CMS, Roy Lennartson, admitted that there were problems, but gave examples of action being taken to remedy sanitation inadequacies. In November 1971 the General Accounting Office submitted yet another report to Congress on enforcement of Federal sanitation. Accompanied by CMS employees the staff was basically following up on a review a year earlier. They found many of the conditions little changed from those observed earlier, due to lack of day to day enforcement and insufficient supervisory review. The report still cited the need for Washington officials to convince local inspectors that consumer protection should be the main objective of sanitation. It also reported an excessive amount of moisture in poultry inspected.

In the meantime, the Department had taken some action to enforce standards by sending letters to supervisory and inspection personnel outlining procedures and assuring support. It also issued revised procedures, instructions, and forms including criteria for withholding or suspending inspection.

In August 1970, two consultants were hired by the Consumer and Marketing Service to review the program. In November the Secretary announced the reorganization of the work in line with their report, a separate division for sanitation and plant facilities, and a single unit combining all Washington review and inspection staffs reporting to the Administrator. The consultants also recommended that the consumer protection functions of CMS be placed in a separate agency. While this report was being prepared, a CMS review team visited many of the same places inspected by GAO personnel. Operations were suspended at 13 plants for correction of sanitary deficiencies.

CMS continued to object to the creation of a separate consumer protection agency. GAO continued to urge a separate agency. Moreover, it urged Congress to establish a separate Department of Consumer Affairs. On April 2, 1972, meat and poultry inspection work was transferred to the new Animal and Plant Health Inspection Service.

A 1976 General Accounting Office report was done at the request of Senator Philip A. Hart. Investigators found that some plants surveyed were actually approved for Federal inspection and should not have been included. Moreover,

it reported that the instructions for the survey should have been issued "in a timely manner via teletype writer." Further it raised questions on the validity of some reports.

Another report by the General Accounting Office was prepared in 1977, following the completion of the Booz-Allen and Hamilton report. It reviewed the inspection of meat and poultry processing plants and the advantage of shifting the emphasis from continuous inspection to the quality control approach. The report recommended changes in the Federal legislation covering meat and poultry inspection to enable USDA to implement quality control and unannounced inspection. USDA withheld its comments inasmuch as it was awaiting other reports on the inspection system.

The use of animal drugs, pesticides, and environmental contaminants have had an impact on meat and poultry inspection. Beginning in 1967 USDA has had an evolving residue monitoring program. Residues have been found at levels far exceeding the established tolerances. USDA shared responsibility with Food and Drug Administration and the Environmental Protection Agency to ensure that such residues not exceed safe levels in raw meat and poultry. In USDA, responsibility was delegated to the Food Safety and Quality Service, established in 1977.

The General Accounting Office investigated this facet of the inspection system in 1978. It questioned the validity of USDA's reports on the percentage of residue violations in its monitoring program. GAO recommended that the Department of Agriculture revise its method of computing residue violation levels and that it expand its monitoring efforts. A basic problem was the delay between the time that samples were sent to the laboratory for checking and the receipt of the result of the tests. USDA did not have the authority to detain raw meat or poultry until results of sample analysis had been made, unless the animal was believed to have residues. Animals were marketed before the sample analysis had been completed. Then meat in violation of residue levels could not be identified. GAO recommended that USDA (1) develop a tagging system to mark the tested animals, (2) develop residue analysis that could be completed before the carcass left the slaughterhouse, and (3) place greater emphasis on residue testing by industry. The Department, in turn, reported that it did have a program for industry cooperation in monitoring that allowed rapid corrective action. But followup efforts had not been effective. GAO recommended that Congress amend the Federal meat inspection act to provide for USDA quarantine authority to prevent marketing of animals by a violating grower until corrective action had been taken. The act should further enable USDA to require growers to place identification tags on animals going to auction or slaughter houses.

A successful program for the producer, the Government, and the consumer requires a careful interrelation between the Department of Agriculture, the Food and Drug Administration, and the Environmental Protection Agency.

In 1979, as the costs to the Federal Government were increasing, the General Accounting Office made an overall study of possible expansion of the application of user charges by Federal agencies. At the time, the Office of Management and Budget withheld its endorsement of the proposal because of judicial opinions and the necessity for enabling legislation. Earlier, Title V of the Independent Offices Appropriation Act of 1952 had granted general authority for the imposition of user fees, but agencies were hesitant to utilize this. When GAO reported in 1981 on USDA's needing authority for the imposition of user fees, it came out strongly that since meat and poultry inspection were mandatory services that provided "a broad public benefit, financing its costs (except for overtime and holiday work) with appropriated funds," as currently provided by law, was appropriate. Therefore, user fees were not appropriate. USDA had started a voluntary quality control program system for industry in September 1980 to reduce costs of the inspection program. GAO was recommending a mandatory quality control program (to be developed by industry) with unannounced inspections.

Costs of meat and poultry inspection had tripled in the decade of the seventies. In part, this increase had been due to inflation, and in part to USDA's taking over State inspection programs as provided in the Wholesome Meat Act of 1967 and the Wholesome Poultry Act of 1968. Between 1970 and 1978, the Department of Agriculture had taken over 21 State meat and 29 State poultry inspection programs. The number of Federally inspected processing plants increased 70 percent while the number of processing inspectors only increased 30 percent. And USDA was expecting costs to continue to increase. Action was needed to reduce costs.

Overall supervision of meat and poultry inspection programs was assigned to the Food Safety and Inspection Service on July 17, 1981, with the assignment of other grading and inspection service from Food Safety and Quality Service to the Agricultural Marketing Service. In July 1981, the General Accounting Office reported on its investigation of sanitation and Federal inspection at slaughter plants. Accompanied by supervisors from the Food Safety and Inspection Service, the team made unannounced visits to 62 randomly selected meat and poultry slaughter plants in six States.

They found that 26 percent were not in compliance in one or more of the six basic inspection program requirements. As of February 21, 1981, due to hiring and budget restrictions, the Service had a seven percent shortage among its slaughter plant inspectors. As a result, inspection was not as thorough as it should have been. Sanitation deficiencies included dripping and condensation contaminating carcasses; dead flies on meat work tables and meat dragging through dirty drip trays. Inadequate pest control programs resulted in rodents in storage rooms and buildings. Some buildings had problems inside and outside with flies and insects. One plant had inadequate controls of insecticides to insure their proper use. Sixty three percent had water system deficiencies that could result in contamination. Recommendations were sent to the Secretary of Agriculture. Oral comments were made by USDA officials. Final recommendations to the Secretary of Agriculture asked that the Administrator of the Food Safety and Inspection Service emphasize to meat and poultry inspection supervisors the importance of bringing plants up to acceptable levels of compliance, provide these supervisers with improved rating criteria that would specify review findings requiring an unsatisfactory rating overall and in specific areas, and require supervisors to document results of monthly plant reviews.

Another facet of meat inspection reviewed by the General Accounting Office was the question of mechanically separated meat (MSM), and mechanically separated poultry (MSP), that contain some pulverized bone marrow and some minerals that may prove harmful. Products made with MSP were first commercially sold in the United States in the 1960's. In 1969 USDA published regulations that have not been amended and are still in effect, covering the labeling of boneless poultry and products made with MSP. Bone residue in poultry is limited to 1.0 percent. Bone particles in red meat are not to exceed 0.85 milligrams in size or 0.75 for calcium. USDA requires only that the product label specify the species used such as chicken or turkey. The Department of Agriculture established specific standards for MSM in 1974 and labeling standards in 1978. Consumer protection organizations, producers, and the Federal meat inspection agency were frequently at odds over the appropriateness and adequacy of the MSM standards and labeling requirements.

In view of this, FSIS did not plan to establish standards for mechanically boned poultry until the problems with MSM were resolved. Meanwhile, the absence of such standards raised the question of the presence of higher quantities of calcium and cholesterol in products made with MSP than in hand separated poultry. Poultry firms were able to use the relatively inexpensive MSP in poultry products, whereas MSM was limited by the standards and labeling requirements. Thus in 1979 about 300 million pounds of MSP products were produced and only 2.3 million pounds of MSM products out a potential 351.7 million pounds.

GAO recommended that specific standards be established and that labeling requirements be determined for MSP and products made with MSP. It also suggested standards for maximum amount of fat and water in chicken sausages and that sampling and testing procedures be established to determine compliance with these regulations. Further, GAO urged the Secretary to direct FSIS to reduce its verification of quality control system of plants with good records of compliance, to enforce its procedures to investigate and resolve discrepancies on split sample results between FSIS field laboratories and accredited industry laboratories, to reduce the backlog of samples at field laboratories, and to encourage plants to use nearby accredited laboratories. FSIS reported that it was working on resolving these problems.

Through the years Congress has held hearings on proposed legislation for changes in the livestock meat and poultry inspection programs. Studies have been made by Congressional committees from time to time and more recently by the Congressional Research Service of the Library of Congress. As the General Accounting Office expanded its activities to include investigations of the operation of governmental functions, a number of reports were made on the meat and poultry inspection and the import inspection programs. Recommendations were made to the Secretary of Agriculture for needed changes in implementation, many of which have been adopted by the Department.

Other Reports

The Economic Research Service has prepared a number of regulatory impact statements for the Food Safety and Inspection Service to determine the economic impact of proposed changes in regulations. Among these have been label changes to allow the sale of nitrate and nitrite free processed meat products by their familiar product names; modified traditional poultry inspection to speed up the inspection rate; adoption of a national young chicken inspection rate; and the use of protoelectric enzymes to tenderize meat, already authorized for beef cuts and labeling to indicate the use of the enzyme.

In May 1972, the Office of the Inspector General (OIG) completed its audit of meat and poultry inspection work. In

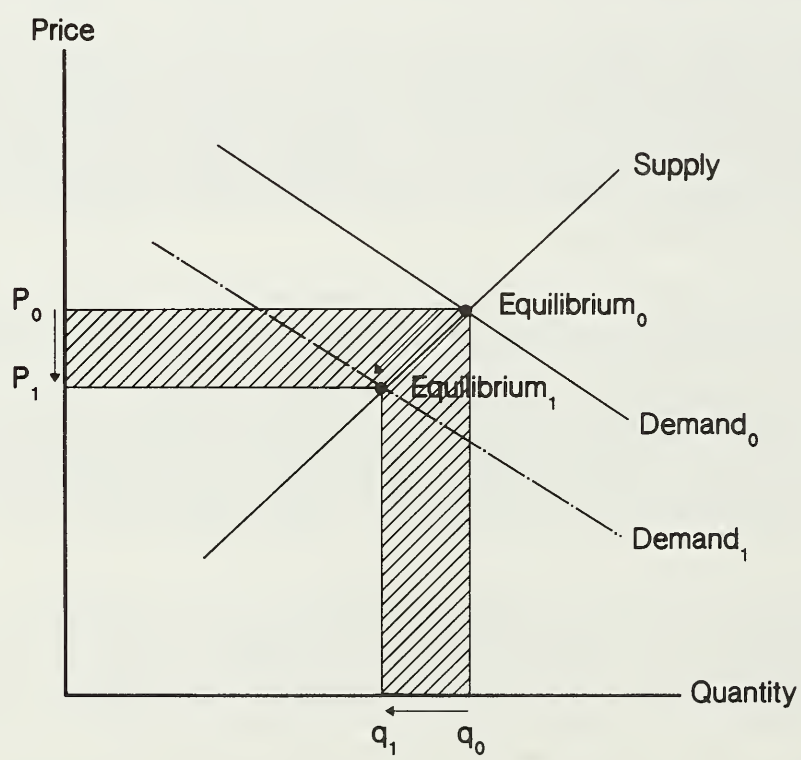
the period investigated, there had been a number of organizational changes made with the concomitant uncertainties and delayed action that had their impact on the operation of the inspection programs. The import inspection program suffered from inadequate direction by most regional directors and insufficient coordination of operations of the Bureau of Customs, the Food and Drug Administration, and the meat and poultry inspection work. In its comment on the report, the associate administrator (APHIS) in charge of meat and poultry administration, who had conferred with OIG about is findings, described the steps taken to remedy some of the problems—a statement that was included in the final report on the investigation.

THE ECONOMICS OF MEAT INSPECTION*

The justification for U.S. Federal meat inspection was economic—European countries were banning imports of U.S. salted pork and bacon because of trichinosis. The loss of foreign markets reduced the demand for pork bellies from D_0 to d_1 in figure 3. As a result, the quantity of total U.S. pork bellies sold domestically and overseas declined from q_0 to q_1 and the price fell from p_0 to p_1. Producers lobbied for a Federal meat inspection program for exports which was enacted in 1890.

Figure 3

Reduction in the Demand for U.S. Meat with the Loss of the European Market



Today foreign trade in meat and poultry products is even more important since freezing and refrigeration permit more perishable cuts to be transported greater distances to market. In 1983 meat and poultry exports were $1.2 billion and imports were $2.1 billion (Table 1). Yet the safety of our meat supply remains an issue. In 1984 and 1985 European technicians surveyed more than 400 American meat packing plants and found them below European Community (EEC) standards. Some of the differences reflect sanitation and others inspection methodology.

*This section was prepared by Tanya Roberts, Food and Agricultural Policy Branch, Economic Research Service, United States Department of Agriculture.

Table 1. Value of Meat and Poultry Food Exports and Imports, United States, 1983

Product	Imports	Exports
	-million dollars -	
Beef	1,360	610
Pork	619	225
Poultry	31	278
Other Meats	63	79
Total	2,074	1,192

Note that dairy products and fats are excluded.
Source: U.S. Foreign Agricultural Trade, Statistical Report, calendar year 1983.

How the safety of the meat and poultry is affected is viewed differently by the EEC and the U.S. "According to the USDA, differences include such issues as systems used for cleaning vehicles and disinfecting plants, types of equipment allowed in U.S. plants, the extent of veterinarian involvement in the inspection process, post-mortem inspection procedures and certification of plant employees' health." There are two issues here: the actual healthfulness of meat and poultry as well as perceived safety. Both are necessary to maintain product demand.

An ERS report examined current USDA inspection procedures for three cattle diseases transmissible to humans. The human health protection benefits of inspecting for these three diseases - tuberculosis, tapeworm, and septicemia were difficult to quantify, and the estimate had a wide range from a low of $65 million to a high of $2.2 billion annually. These three diseases were chosen for a number of reasons. First, these diseases were the easiest to make linkages from animals to humans which meant that the inspection reporting form had to list the condition as a separate category and that the scientific data on epidemiological linkages were sufficiently rich. Second, all three disease conditions are, or were, important in terms of their prevalence in animals.

Third, each represents a different type of human health hazard. Tuberculosis is caused by a bacterium and is transmitted through the air from the live animal or its carcass to farm families, slaughterhouse workers, or processing plant workers. *Taenia saginata* is a parasite and human tapeworm infections come from eating a live larva imbedded in muscle tissue. Septicemia caused by *E. coli*, another bacterium, probably can be transmitted to humans through consumption, contact, cross-contamination of other foods, etc. The epidemiology is still sketchy and the pathogenic characteristics of *E. coli* are not well understood. Last, none of the three animal diseases are easily preventable. . . while we can treat TB and tapeworm in humans, there is no effective treatment or vaccine for cattle. (While some new vaccines for calf scours caused by *E. coli* have been marketed in the last couple of years, it is not clear whether the vaccine would have any effect on the *E. coli* causing septicemia.)

Because of the wide range of the estimates, definitive conclusions about the cost effectiveness of the present meat inspection system, costing somewhat over 300 million Federal dollars, cannot be drawn. However, the data do suggest that some Federal effort is cost effective:

- There are a wide variety of viral, bacterial, and parasitic infections that are common to animals and humans and can probably be transmitted from food animals to humans.

- Because consumers cannot easily determine the healthfulness of meat and poultry products, there are opportunities for industry members to compromise product quality to cut costs.

- The high and the low estimates for these three diseases do bracket the total costs of the Federal inspection program which suggests a more complete accounting of the human disease prevention consequences of Federal inspection would be significantly greater than program costs.

"Free" markets, those without public intervention, do not have incentives to provide "safe" meat because buyers cannot readily determine the safety of the product. Most contaminants are microscopic. The connection between meat

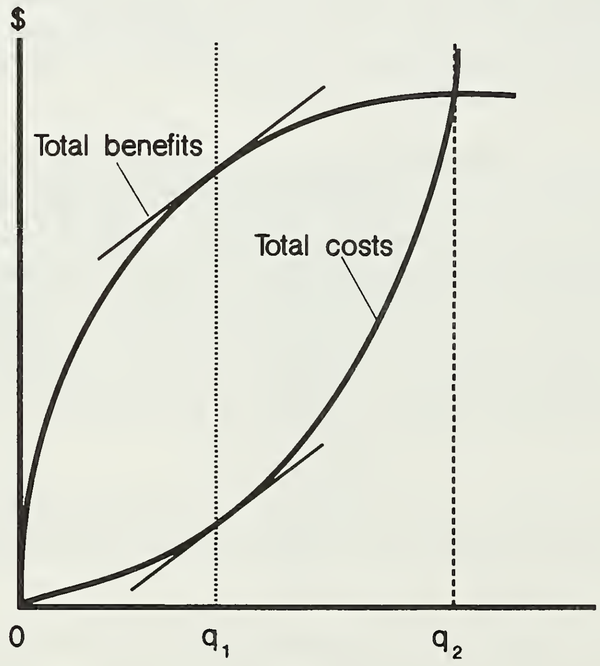
and disease is often unclear since many diseases take days, weeks, or months to occur. Many symptoms are vague and may mimic the "flu;" and the product has already been eaten and cannot be examined, and causality cannot be determined. Furthermore, the farm or firm responsible often cannot be identified, many animals lack identifying marks and the meat is frequently rehandled and sold under a generic name as it moves through the marketing system. Such loss of identity, which impedes tracing a product back to the origin of a hazard, can protect an offending firm from detection and involvement in civil suits and payment of claims. In the past year the American Meat Institute and the National Pork Producers Council have endorsed mandatory producer identification programs for swine sent to slaughter.

Consumer protection activities (for example, visual and/or laboratory examination for disease, better refrigeration, or disposal of slightly spoiled products) add to the cost of production. Individual firms in a "free" market have little incentive to cover expenses for a relatively nebulous feature such as product safety which probably cannot be traced back to the offending firm. These market conditions create a demand for product safety assurance to be supplied by an organization with recognized objectivity, such as the government.

Figure 4 illustrates the relationship between the total cost function for more intensive inspection of a given quantity of meat or poultry and the total benefit function to society from the resulting reduction in health hazards. Minimal inspection might consist of nothing more than observation of the product's color or odor indicating off condition. But inspection procedures for detecting chemical residues or microscopic evidence of disease considerably increase inspection costs. As the inspection program attempts to find and remove more health risks, the cost function would increase astronomically.

Figure 4

Total Benefit and Total Cost Functions By Level of Inspection Intensity and the Resulting Hazard to Human Health



Total benefits increase with the level of inspection because human disease contracted from meat and poultry declines. However, if major health risks are detected and removed first, the benefit function will have a diminishing slope indicating that incremental benefits decline as inspection efforts increase.

Although figure 4 indicates that total benefits and costs are equal at the q_2 level of inspection service provided, this is not the optimum level of use for inspection resources. *The optimum level, q_1, is where the incremental gain in benefit equals the incremental increase in cost.* The equality is shown by the slopes of the two curves; note that at q_1 the slopes are equal (when tangents to the curves are parallel; the slopes of the curves are equal). The use of resources greater than q_1 would increase costs more than benefits. A reduction in inspection service below q_1 would

reduce benefits more than costs. Consequently, the optimal use of inspection resources does not eliminate all health risks from consumption of this quantity of meat products.

Analogous reasoning applies to products which are adulterated, such as water added to ham above allowable limits. The role of the inspector again is to minimize such practices not readily detectable by the consumer at the point of purchase. Implicit in such policing is a standard for the amount of water permitted in meat and poultry products. In March 1986, a turkey company in Utah was found guilty of adulteration for substituting water for poultry meat in formulations for school lunch programs and adding chlorine to products to mask spoilage.

Inspection does not have to be a Federal Government function. Inspection could be carried out by the private industry, religious groups, or cooperatives. However, there are at least two advantages to a Federal effort. First, Government has the police powers required to enforce regulations. Under rigorous enforcement, no single firm has the incentive to lower standards and save costs by selling less safe meat and poultry products. Second, a Government system may instill more consumer confidence than a privately-controlled one and consequently the demand for meat would be greater. (Consider a baseball league where the umpire is paid by the home team, not by the league.)

Current Federal, State, and local inspection procedures both instill consumer confidence and limit firm liability as long as regulatory procedures are followed. However, many of these inspection systems were established at the turn of the century. The National Academy of Science (NAS) has recommended adoption of state-of-the-art techniques for the Federal meat inspection system. The changes would make more explicit the connection between specific inspection procedures and the likely impact on the healthfulness of meat and/or poultry.

Inspectors with USDA's Food Safety and Quality Service check carcasses to make sure meat is safe and wholesome.

Under a USDA contract, NAS is conducting a risk assessment of current poultry inspection procedures. One cautionary voice at NAS hearings is the National Association of Federal Veterinarians which is concerned that modern processing may be contributing to the increasingly prevalent human diarrhea associated with poultry. Singled out were the mechanical evisceration machines, common water baths that spread contamination, and a relaxing of federal regulations which permit carcass washing instead of trimming away contaminated parts.

CONCLUDING OVERVIEW

The mission of the meat and poultry inspection systems has broadened in their nearly a century of operations. The initial act of 1890 was aimed at insuring healthful food for shipment abroad—to protect our export trade. The act of 1906 has been interpreted as having as its mission "to prevent improper products from reaching consumers." The acts of 1967 and 1968 sought to develop a plan by which state systems were "equal to" the requirements of the Federal inspection legislation. In 1977, meat and poultry legislation had as its goals consumer protection in intra-state, interstate, and foreign commerce; protection of markets; and for poultry a clear instruction not to allow a capricious condemnation of products. However, in late 1985, our export trade was again threatened when some of the European Economic Community nations challenged the thoroughness of the inspection in some companies.

Animals Inspected Under Federal Meat Inspection,
1891 - 1985
(in thousands)

1891	84	1927	70,747	1963	111,967
1892	3,809	1928	75,272	1964	114,794
1893	4,886	1929	73,881	1965	107,457
1894	12,627	1930	74,926	1966	107,567
1895	18,883	1931	74,406	1967	114,764
1896	23,165	1932	77,900	1968	119,604
1897	26,581	1933	75,323	1969	120,202
1898	31,117	1934	77,569	1970	122,490
1899	34,163	1935	72,736	1971	131,504
1900	34,738	1936	61,970	1972	123,563
1901	37,028	1937	71,223	1973	114,079
1902	38,904	1938	65,970	1974	121,580
1903	37,262	1939	71,118	1975	116,572
1904	39,590	1940	78,751	1976	120,692
1905	40,221	1941	82,064	1977	123,927
1906	42,901	1942	93,683	1978	120,244
1907	50,935	1943	103,801	1979	124,628
1908	53,973	1944	112,682	1980	131,548
1909	53,672	1945	83,760	1981	129,219
1910	49,179	1946	81,813	1982	122,970
1911	52,977	1947	83,648	1983	128,966
1912	59,014	1948	83,534	1984*	127,654
1913	56,323	1949	85,289	1985*	120,579
1914	56,909	1950	88,011		
1915	58,023	1951	89,374	*Fiscal Years	
1916	62,101	1952	93,997		
1917	63,708	1953	93,056		
1918	58,630	1954	93,439		
1919	70,709	1955	102,614		
1920	65,332	1956	108,292		
1921	62,252	1957	100,964		
1922	63,196	1958	95,523		
1923	73,398	1959	104,617		
1924	79,814	1960	104,965		
1925	75,660	1961	105,801		
1926	68,289	1962	108,057		

An idea of the expansion of the meat inspection may be gained from the fact that in 1906 the system operated in 163 establishments in 58 cities with about 760 employees, of whom about 300 were veterinarians working under an agency appropriation of $1,000,000.

From 1971 to 1981 the volume of meat and poultry processing inspection increased about 60 percent or from about 4,300 establishments in 1971 to 6,800 in 1981, many of them small plants. The cost of these processing operations grew from $28 million in 1971 to $76 million in 1981.

In 1984, the appropriation for Food Safety and Inspection Service, the agency administering the now complex program was $333,696,000 with a supplemental appropriation of $4,362,000. There were 1,282 veterinarians, 7,729 food inspectors, 232 clerical and administrative employees, and 1,136 scientific and other employees, for a total of 9,023 full time and 1,356 part-time people.

The meat and poultry inspection service has proved its value in many fields as well as its primary purpose—to insure the cleanliness and wholesomeness of meat and poultry and their products. The records have provided an important index to trends of production, imports, and exports as well as the extent of diseases. These have been an element in disease control.

Moreover, scientific and technological phases have taken the agency far beyond the basic inspection of meat, poultry, and related products. The staff is working on new scientific tests for inspectors in plants or at ports. Laboratories are developing new analytical procedures and technology to speed up testing. Attention has been directed to refining and modernizing inspection standards and procedures. And to keep the staff aware of new developments, a continuing education program has been operating. Conversely a Meat and Poultry Hot Line has provided a channel for consumer inquiries, handling 1,674 calls in 1983.

There is every reason to believe that the agency will continue to both develop and adjust to new technology and will continue to protect the consumer.

Poultry Inspected Under Federal Inspection
(Thousands)

	Chickens	Turkeys	Others	Rabbits
1968	2,459,407	110,571	10,921	
1969	2,580,057	97,141	11,861	
1970	2,837,967	98,290	12,701	
1971	2,934,708	112,303	12,604	
1972	3,075,432	115,545	12,506	
1973	3,099,621	123,408	12,571	
1974	3,155,392	131,435	12,131	
1975	3,018,731	119,176	12,660	
1976	3,286,351	127,087	13,030	
1977*	3,537,433	128,324	14,983	
1978*	3,724,977	132,115	16,680	
1979*	4,093,730	147,227	18,866	
1980	4,135,202	159,217	18,523	
1981	4,264,543	163,968	19,370	
1982	4,275,307	161,153	20,386	
1983	4,346,278	165,627	21,763	738
1984	4,376,253	162,671	21,245	846
1985	4,615,750	172,030	22,463	827

*Calendar years. All others are fiscal years.

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PART VI
AVIAN INFLUENZA

By
Kay W. Wheeler

Area Veterinarian in Charge, Harrisburg, PA, Animal and Plant Health Inspection Service, United States Department of Agriculture

The story of the Bureau of Animal Industry has been a success story. Some undertakings have required more effort and time than others. But in the end, many of the disease eradication goals which have been identified have been accomplished, and diseases important to American agriculture have been eliminated from the United States.

Even as the first century of existence for the Bureau of Animal Industry was drawing to a close, another challenge was presented. In early 1983, a relatively mild form of avian influenza appeared in southeastern Pennsylvania's poultry industry. The industry and local regulatory officials immediately became concerned and began to monitor this new threat. Pennsylvania is the fourth largest egg-producing state and 70 percent of our nation's poultry industry is located in the eastern poultry states.

BACKGROUND

"Fowl plague," one form of avian influenza, was first recognized by researchers in Italy during 1878. Laboratory investigation showed that the disease was caused by an organism which could not be seen under the microscope and which could pass readily through a ceramic filter that would stop most bacteria. Thus fowl plague joined foot-and-mouth disease and African horsesickness as diseases of domestic animals caused by filterable viruses.

Early in the 20th century, fowl plague spread throughout Europe. In 1923, a laboratory worker illegally imported the virus into the United States for research purposes. During the next year, the virus was allowed to escape from the laboratory, and approximately a half-million birds became infected and died. The disease then spread along the East Coast to a number of poultry farms but was eradicated within a year. The disease erupted again in New Jersey in 1929 but was quickly eradicated.

During the 100 years since fowl plague was first recognized there have been tremendous advances in the study of diseases and disease causing agents. It has been accepted for the past 30 years that the organism which causes fowl plague is a part of the influenza virus group. Fowl plague is an inexact term applied to certain outbreaks of influenza which resulted in especially high death loss.

> The term "fowl plague" had become an emotive, quasi-legal term which although originally used to define a clinical disease had become, by incorrect usage, to be understood by different groups of workers to mean: specific virus isolates; any influenza virus of H7 subtype causing high mortality. It is clear that to avoid future confusion the term is best abandoned (1).

The fact that avian influenza viruses have such wide variation in virulence among the various serotypes has confused the issue for many years. In an effort to alleviate that confusion, when the First International Symposium on Avian Influenza met in Beltsville, MD, in April 1981, the group made the recommendation that, ". . . the term Fowl Plague be discarded, except for historical purposes."

Characteristics of the Virus

Avian influenza (AI) is one of the type A influenza viruses. The type A influenza viruses can infect both birds and mammals. The infectivity for various species is related to the surface spikes of the virus which contain hemagglutinin (H) and neuraminidase (N). There are thirteen different hemagglutinin subtypes and nine neuraminidase subtypes which have been identified. The various combinations of surface antigens would allow for at least 117 virus subtypes. The number of pos sible combinations is actually much higher because the RNA (Ribonucleic acid) genetic information is carried on eight separate pieces within the virus.

These pieces can combine in various ways when two different influenza viruses infect a cell at the same time (2). It is presumed that just such a genetic recombination resulted in the H5N2 virus subtype which appeared as a mild disease in southeastern Pennsylvania's poultry population. The virus causing the mild form of the disease probably originated from wild waterfowl which commonly carry AI viruses. The virus then changed in the chicken population to the highly pathogenic form.

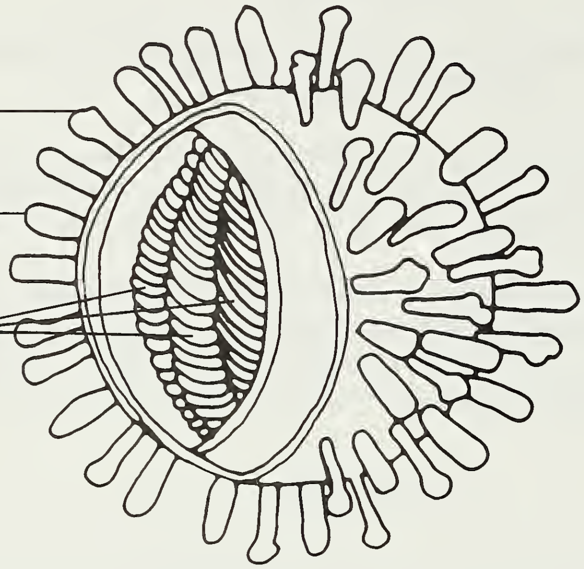


Illustration of influenza virus. An artist's concept of an avian influenza virus showing the H and N surface antigen spikes and the RNA strands which carry the viral genetic information.

THE AVIAN INFLUENZA OUTBREAK
Chronology—1983

APRIL: The first two cases of avian influenza were diagnosed by the University of Pennsylvania New Bolton Center Laboratory. One flock in "forced molt" showed an increased death loss. Another flock with 95,000 layers had a 31% drop in production, an increased death loss, and severe respiratory symptoms. National Veterinary Services Laboratory (NVSL), Ames, IA, confirmed the virus to be Influenza A, serotype H5N2. At this time the virus did not produce disease when inoculated into test birds in the laboratory.

Task force diagnosticians visited farms to take samples from birds to test for the presence of the avian influenza virus. In the early days, the daily death loss in flocks quickly outstripped the ability of individual farmers to deal with disposal.

MAY: One additional farm was affected, a flock with 90,000 layers had a production drop of about 25%.

JUNE: Six farms were affected with 365,000 broilers having variable death loss up to 10% and 214,000 layers having production loss up to 20%.

JULY: Six farms were affected, 173,000 broilers with low death loss and 527,000 layers having variable production loss up to 40%.

AUGUST: Two farms were affected, 204,000 broilers with variable death loss up to 3%.

SEPTEMBER: Ten farms were affected with 974,000 layers having death loss as high as 33% and production loss up to 22%; 272,000 broilers with death loss up to 10.4%; 8,000 breeders with drop in production of 33%. Throughout this entire 6-month period, the virus from specimens taken from Pennsylvania poultry flocks consistently failed to kill test birds at NVSL.

OCTOBER: Eleven farms were affected including pullet and hatchery operations. The clinical signs included facial edema with swelling of the head, swelling and cyanosis of the comb and wattles - sometimes with vesicles, swelling of the shank/hocks, and internal petechial hemorrhage. Production dropped as much as 65% in some flocks and death losses were as high as 10%. The first highly pathogenic avian influenza (HPAI) was tentatively diagnosed. At this time, the term "highly pathogenic avian influenza" was defined according to the criteria established by the International Symposium on Avian Influenza, April 22-24, 1981:

> That influenza virus highly pathogenic for avian species be considered any influenza virus that results in not less than 75% mortality within 8 days in at least 8 healthy susceptible chickens, 4-8 weeks old, inoculated by the intramuscular, intravenous, or caudal airsac route with bacteria-free infectious allantoic or cell culture fluids. This assumes the use of standard operating procedures to assure specificity.

By October 26, the laboratory criteria for diagnosis of HPAI was standardized to meet the recommended definition of the 1981 International Symposium. The National Veterinary Services Laboratory was prepared to provide additional laboratory support. On the next day, the criterion for mortality of test birds was met with samples submitted to NVSL from flocks in Pennsylvania. On October 28, the Pennsylvania Department of Agriculture (PDA) issued a proclamation of a "dangerous transmissible disease" of poultry. On October 31, 1983, the reisolation of HPAI virus from test birds was confirmed by NVSL. Highly pathogenic avian influenza, type H5N2, officially existed in southeastern Pennsylvania.

Information from the Data-Bank

The collection of all available technical information began as soon as it had become evident that avian influenza in southeastern Pennsylvania had the potential for becoming a threat to the poultry industry. The Technical Support Staff, Emergency Programs, Veterinary Services, used its information data-bank on animal diseases in compiling the needed information. It is through the rapid access to technical literature worldwide that an appropriate early response can be made to various animal diseases of economic concern. The ability to compare diseases allows the guidelines for eradication which have been previously developed for other diseases to be utillzed when they fit a current situation.

Avian Influenza Technical Collaborators

During the 87th annual meeting of the United States Animal Health Association (USAHA) in Las Vegas, NV, there was concern about the avian influenza outbreak in Pennsylvania. It was recognized that the disease was showing a progressive increase in pathogenicity. Following the USAHA meeting, a group of experts were invited to act as an advisory group in determining the actions to be taken in dealing with avian influenza. Seven of the ten members of the group came from the USAHA Committee on Transmissible Diseases of Poultry. Three other members were invited to join the group to contribute their expertise on specific facets of the problem. The avian influenza technical collaborators met in Hyattsville, MD, on October 31 and November 1, 1983, to discuss the changing avian influenza situation. During the meeting, information was solicited from Federal, State, and industry sources.

The technical collaborators concluded that:

1. The highly pathogenic avian influenza virus disease causing high mortality and dramatic symptoms found in Penn-

sylvania is a problem that is not endemic to the United States. The current geographical distribution for occurrence of this disease is confined to a relatively small area in Pennsylvania, and every effort should be made by State and Federal agencies and the poultry industry to contain the disease.

2. The highly pathogenic avian influenza problem presented to the Pennsylvania poultry industry presents a potential threat to the entire poultry industry of this nation.

3. The unique disease-causing virus appears to be highly pathogenic and appears to be increasing in virulence during October.

4. There is no scientific explanation for the increased virulence of this disease in recent weeks.

5. (This group) is totally cognizant of the dire lack of scientific information available at this time to predicate sound control but is of the opinion that the State and Federal animal eradication recommendations, disease control agencies, and the Poultry Industry must take every step necessary to protect the entire poultry industry from the disease, as well as considering the economic impact involved with interstate and international commerce.

6. The last time an avian influenza outbreak resulted in severe losses in chickens in the United States was during the Fowl Plague outbreak of 1929 in New Jersey. Prompt action by State and Federal regulatory officials and industry at that time resulted in eradication of the disease.

The recommendations made by the technical collaborators dealing with avian influenza were:

1. That the Secretary of Agriculture declare a national emergency, thereby providing the funds and staff to provide a cooperative State-Federal-Industry eradication program for the highly virulent avian influenza.

2. That the USDA recognize the needs for additional scientific information regarding avian influenza in chickens, turkeys, free-flying birds, and the other means of transmission, such as flies and rodents, and provide the means to develop the much needed research.

3. That the (group) recommends that the respective State regulatory officials cause avian influenza to be a reportable disease.

4. That the (group) recommends that an immediate Federal quarantine be utilized in geographical areas where the highly pathogenic avian influenza has been diagnosed, and that the State-Federal animal health officials take every step to safely dispose of all dead and diseased birds.

5. That the USDA continue to utilize this (group) as a collaborating body to assist in the policy and programming for a successful effort to contain and eradicate highly pathogenic avian influenza in poultry.

The following individuals made up the membership of the Avian Influenza Technical Collaborators:

Dr. H. E. Goldstein, Chairman, Ohio State Veterinarian, Columbus, OH
Dr. R. A. Bankowski, University of California, Davis, CA
Dr. C. Beard, Southeast Poultry Research Station, ARS, Athens, GA
Dr. F. R. Craig, Perdue Farms, Inc., Salisbury, MD
Dr. B. Easterday, University of Wisconsin, Madison, WI
Dr. L. C. Grumbles, Texas A&M University, College Station, TX
Dr. F. Hayes, University of Georgia, Athens, GA
Dr. R. H. McCapes, University of California, Davis, CA
Dr. B. S. Pomeroy, University of Minnesota, St. Paul, MN
Dr. R. G. Webster, World Health Organization Influenza Center, St. Jude Children's Research Hospital, Memphis, TN

The Federal Quarantine

Upon returning to his office, following the technical collaborator's meeting in Hyattsville, MD, the Pennsylvania State

veterinarian further defined the status of the problem:

> Following adjournment of the Advisory (Group's) official proceedings, members of the (group) discussed with Pennsylvania and USDA officials possible control measures and the feasibility of eradication of the highly pathogenic form of avian influenza. Until the details of Federal involvement are established the group felt that the PDA should adopt the following minimal regulatory actions:

1. Immediately quarantine all known infected or suspicious flocks.

2. Establish a general quarantine of the immediate problem area and an encircling five mile influenza-free buffer zone.

3. Permit absolutely no movement of poultry or poultry products infected or exposed to the highly pathogenic disease from the quarantine area.

4. Permit movement of poultry or poultry products from quarantine flocks (premises) by official permit only.

5. Prohibit the further use of vaccine until the feasibility of depopulation with indemnity is determined and the availabilty of indemnity funds is established.

6. Develop appropriate guidelines for proper disposal of infected or contaminated carcasses and litter.

7. Establish guidelines for control of potential vectors of the highly pathogenic disease including insects, rodents, wild animals and birds, domestic pets, and people.

8. Develop a detailed record of the owner and address of every flock of susceptible poultry in the quarantined area.

9. Develop an inventory of all available personnel, equipment, and facilities in the problem area that might be useful in the course of a control and eradication effort. (3)

During a meeting on November 4, 1983, the Animal and Plant Health Inspection Service Administrator and industry officials were briefed by Emergency Programs Staff regarding the extent of the outbreak and the possible levels of the Federal response.

Later that same day, a Federal quarantine was placed on Berks, Dauphin, Lancaster, and Lebanon Counties, PA. A total area of 1,125 square miles was quarantined.

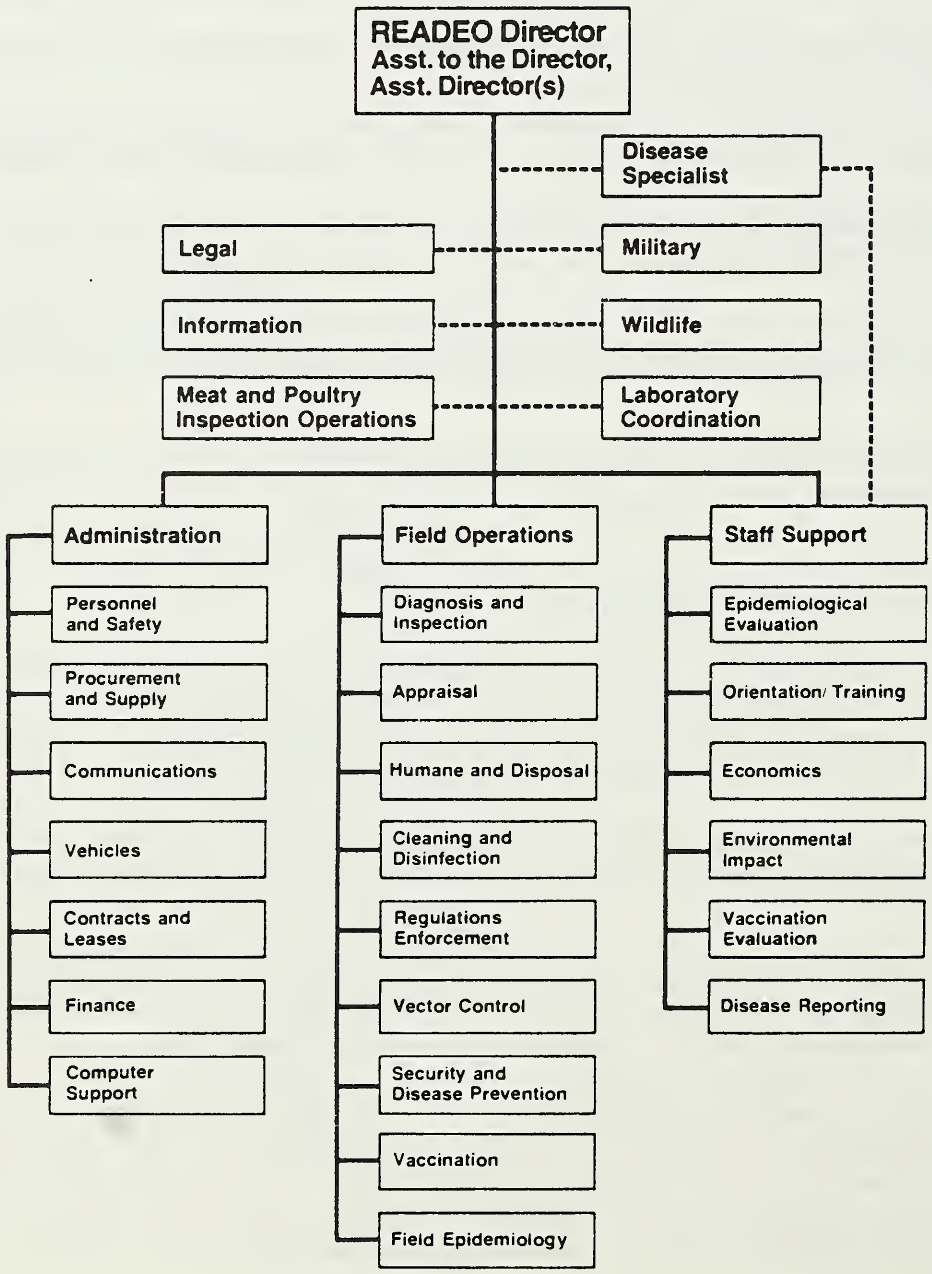
The Veterinary Services Northern Regional Emergency Animal Disease Eradication Organization (READEO) was activated in order to enforce the Federal quarantine:

> In order to minimize the danger of a foreign animal disease gaining a foothold or spreading throughout the United States, APHIS has developed emergency animal disease eradication organizations. These units or teams are organized on a regional basis and each is known as a Regional Emergency Animal Disease Eradication Organization (READEO). They operate within the framework of the existing Veterinary Services regions.
>
> These organizations are based on the concept that pre-selected, pretrained units of animal health specialists can eradicate a disease more rapidly and efficiently than groups pulled together at the time an animal disease is diagnosed.
>
> Initially, READEO personnel are selected from within the involved regions. To complete each team, additional personnel may be requested from other Veterinary Services regions. Consequently, personnel may be relocated and reassigned, wherever needed, throughout the United States.
>
> Each Assistant Regional Director for Veterinary Services is responsible to the National Emergency Field Operations Staff, Emergency Programs, for the readiness of a READEO unit. When any READEO is activated, either the Regional Director or the Assistant Regional Director is relieved of all other duties and automatically becomes the READEO Task Force Director. If warranted, a READEO unit may be activated and personnel relocated to another region to assist with disease eradication.

National policy for eradication of foreign animal diseases is implemented through a clear line of authority within the APHIS organization. In the eradication process, day-to-day decisions and directions are provided by the READEO Director. The Director maintains contact with concerned industry representatives and technical disease experts. This procedure assures that decisions are based on the best information available (4).

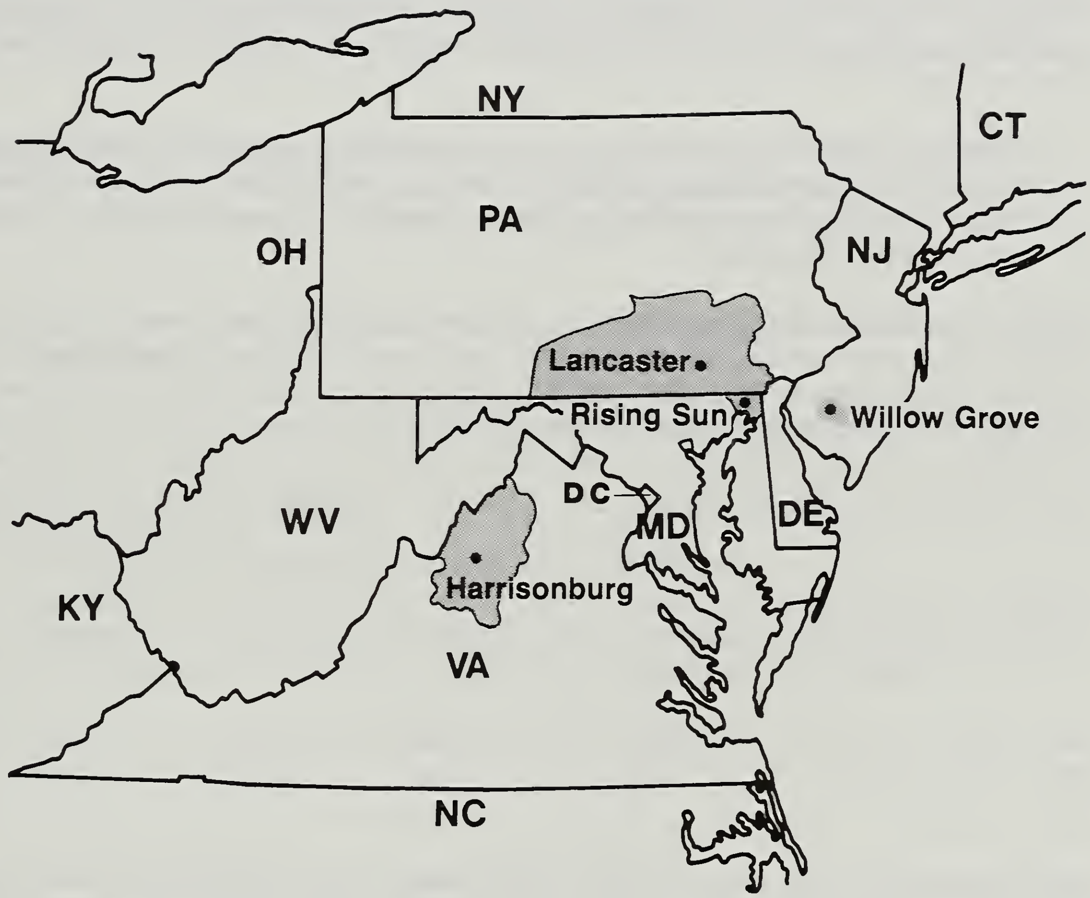
The daily operation of the avian influenza READEO task force began with a morning staff meeting. The staff meeting was originally intended for section heads who were the only ones required to attend. However, the meetings immediately evolved into an informational update for all task force personnel and allowed everyone to have a very real sense of participation in the functioning of the task force. Having the morning meeting open to all task force members contributed significantly to the high morale which was evident in the group.

Regional Emergency Animal Disease Eradication Organization (READEO)



Avian Influenza

Federal Quarantine Areas



February 1984

The Extraordinary Emergency

On November 9, 1983, the Secretary of Agriculture declared an Extraordinary Emergency and authorized the transfer of $12.5 million from the Commodity Credit Corporation to be used for the eradication of avian influenza.

During the two weeks following the emergency declaration, the READEO was fully staffed. The local poultry industry rented space and placed a staff of industry representatives in the same building where task force operations had been established. Industry staff and the task force directors were thus immediately available to each other for consultation or coordination.

Veterinary Services personnel came initially from the Northern Region, and then, as special staffing needs were identified, other Federal personnel were brought in from across the entire country. Acting under the 1965 Memorandum of Understanding, the United States Army Forces Command immediately sent a military liaison officer and a veterinary officer to provide staff assistance. At the request of the task force director, the military provided personnel, vehicles, communications and laboratory equipment, office furniture, and specialized research equipment.

Wildlife specialists from the Southeastern Cooperative Wildlife Disease Study, Athens, GA, joined the task force to study the relationship between avian influenza and wildlife populations. This was discussed in a November 1984 issue of *APHIS Facts*.

> At peak strength in late January 1984, the Pennsylvania task force had 406 people on board—175 permanent Federal, 128 temporary, 38 State, 40 military, and 25 others. At peak strength in Virginia (in March 1984) 279 people were working'out of Harrisonburg: 88 permanent Federal, 179 temporary, 7 State, 2 military, and 3 others (5).

Mixed with the Federal personnel in every aspect of task force functions were State and industry personnel. Because of their more limited numbers, the State and industry people often found their talents in high demand from more than one task force section as the Federal personnel strived to understand and deal with the complexities of the AI situation and the southeast Pennsylvania poultry industry.

NUMBER OF INDIVIDUALS SERVING ON A TASK FORCE

	Federal APHIS	Federal Other	Federal Temp.	State	Military	Other	Total
PA	714	10	399	74	121	50	1368
VA	319	2	237	11	11	8	588

On November 12, 1983, the first flock of poultry infected with avian influenze was depopulated. The first 2 weeks of the Federal involvement ended with an enormous accomplishment: the integration of the diverse groups involved into a functional organization.

Reaction: Restrictions and Embargoes

The declaration of an "extraordinary emergency' in November 1983 brought national and international embargoes and limitations on trade. Initially these actions affected the area of Lancaster County, PA. However, in only a few months time, they also brought an economic hardship to the poultry industry in the entire State and adjacent States.

Further Quarantine, Further Insight

Prior to the "extraordinary emergency,' at least one State, New York, had imposed an embargo on all live chickens, eggs for hatching, and all nest-run eggs that originated in Lancaster and adjacent counties. Massachusetts began requiring a prior entry permit for all poultry entering that State. Rumors of further embargoes were so numerous that

on November 7, 1983, a memorandum was circulated requesting information from the area veterinarian in charge in each State regarding the rumors and requesting the status and intentions of the various States.

By mid-November the Agriculture Commissioner of the State of West Virginia ordered any live poultry being brought into the State from a "present or future quarantine area" be consigned to slaughter under Federal inspection. He further ordered that all eggs from the outbreak area have a USDA certificate indicating that they had been washed, sanitized, and packaged in new containers.

In late November, New Jersey State officials prohibited the entrance of all live fowl poultry manure, and litter originating from the entire State of Pennsylvania except when shipped under prior permit. Day-old chicks, hatching eggs, and table eggs were exempted.

Hawaii quickly followed suit, prohibiting the importation of all birds including poultry originating from or transiting through Pennsylvania.

As the emergency situation continued and containment forced the enlargement of the quarantine area, limitations on trade became broader and included States that bordered Pennsylvania. By the end of the year, there were at least 17 States which had imposed some type of embargo or restriction on poultry from the area surrounding southeastern Pennsylvania.

While various interstate trade restrictions were being implemented, other countries were also making provisions to curtail trade and reduce the possibility of introducing the avian influenza virus. Canada was among the first to refuse entry of all poultry and poultry products originating in the States of Pennsylvania and New Jersey. Switzerland quickly followed suit.

By early December, 1983, six countries had imposed embargoes or restrictions on poultry and poultry products from Pennsylvania and some surrounding States.

On November 16, 1983, the Federal quarantine in Pennsylvania was expanded to include portions of western Chester County, the remaining (southern) portion of Lancaster County, the eastern part of York County, the southeastern tip of Berks County, and a tiny portion of Cumberland County near Harrisburg, PA. The area under quarantine had now more than doubled to a total of 2,500 square miles.

A report filed the next day by a task force poultry epidemiologist gave disquieting testimony to the ubiquitous nature of the virus on infected farms. In this report, the test results from NVSL on environmental swabs collected at one quarantined farm were summarized. Avian influenza virus had been isolated from eggs, equipment, water cups, and flies.

On November 21, 1983, the quarantined area was again expanded to include an additional portion of southwestern Chester County and the southcentral part of York County, Pennsylvania. A total of 3,140 square miles was now under quarantine.

When an avian influenza infected flock was diagnosed in New Jersey, a great deal of concern was generated both within the task force and in "avian influenza" watchers across the country. On November 23, 1983, a Federal quarantine was placed on portions of Atlantic, Cumberland, Gloucester, and Salem Counties, New Jersey. This added a total of 470 square miles to the area previously quarantined. The infection, diagnosed in a flock of layers, was considered to be a direct extension of the avian influenza outbreak in Pennsylvania. Because this extension was confined to a single flock with no further apparent spread, the determination was made to immediately depopulate the farm. The depopulation was carried out on Thanksgiving Day, November 23, 1983, by a group of APHIS and military volunteers from the Pennsylvania task force. It was determined that the quarantine was not needed on a 70 square mile part of Cumberland County, New Jersey. The restrictions were lifted from this area on December 2, 1983, leaving 400 square miles in New Jersey still under quarantine. Another direct extension of avian influenza from Pennsylvania occurred in Cecil County, Maryland, in January, 1984. This incident also involved a single flock and was handled by personnel from the Pennsylvania avian influenza task force.

During the first months of task force activity, the two major program goals were to eradicate highly pathogenic avian influenza and to prevent the spread of the disease beyond the quarantined area. During this period, a great deal of effort was expended in the differentiation between "high-path" and "low-path" avian influenza. It became clear that

the previous HPAI definition determined at the International Symposium on Avian Influenza was not adequate to characterize the disease observed in the poultry houses. Slightly over 40% of the virus isolates from declared flocks failed to kill 75% of the laboratory test birds as required by the previous definition of HPAI (7). Even though the virus failed to fulfill the definition of HPAI in the laboratory, it was producing dramatic clinical and post mortem evidence of disease in poultry flocks in the field.

On December 28, 1983, the avian influenza technical collaborators formally recognized the high-path vs low-path problem and made the following recommendation:

> During the first meeting of the Avian Influenza Technical Collaborators, it was agreed that the initial eradication efforts should be directed at the highly pathogenic form of avian influenza, and later the (group) would consider action to take concerning the low pathogenic form of the virus. Eradication efforts during the first 47 days have been highly successful in containing the disease, but continued progress toward final eradication is being seriously impeded by the presence of the low pathogenic type virus. In view of experiences gained during avian influenza eradication efforts in Pennsylvania and in consideration of the historical association of high pathogenicity in poultry with H5N2 and other H5 serotypes of avian influenza, the (group) recommends that the eradication charge be amended to include all H5N2 and other H5 serotypes of avian influenza-infected poultry in the Quarantine Area and all other high risk locations of possible spread in the United States. This change is recommended because no effective vaccination, therapeutic, or other measures are available for the elimination or control of this devastating infectious disease in all segments of the poultry industry. Eradication remains the only effective program.

As of December 31, 1983, a total of 228 flocks had been declared positive for avian influenza and depopulated. The maps which follow, show the area of the original quarantine and each of the extensions which became necessary. In the case of each extension, an effort was made to contain the disease without unnecessarily restricting the movement of poultry and products from the immediately adjacent unrestricted area.

THE YEAR OF SUCCESS - 1984

The beginning of 1984 brought with it major changes in task force policy. The decision was reached to eliminate all of the "lethal avian influenza" virus from the southeast Pennsylvania poultry population. This included any flock with clinical, epidemiologic, or laboratory evidence of avian influenza. While this decision relieved the unrealistic constraints on the diagnosticians, it produced a communications gap. As late as March 1984, the AI Technical Collaborators made the following observation:

> It was apparent to this (group) that industry was not fully cognizant of the fact that the initial detectable H5N2 (low path) virus and the later detectable H5N2 (high path) virus were identical in classification, and should be considered as one entity for eradication.

Communicating the rationale and scientific reasons for altering task force policy to that of eradicating lethal avian influenza was to remain an unsolved problem. Somewhat later, another more subtle change came with the decision to eliminate all flocks which were serologically positive to H5N2 avian influenza. This final adjustment in eradication policy was the key to eliminating AI as a threat and provided the ability to demonstrate that the virus was no longer present.

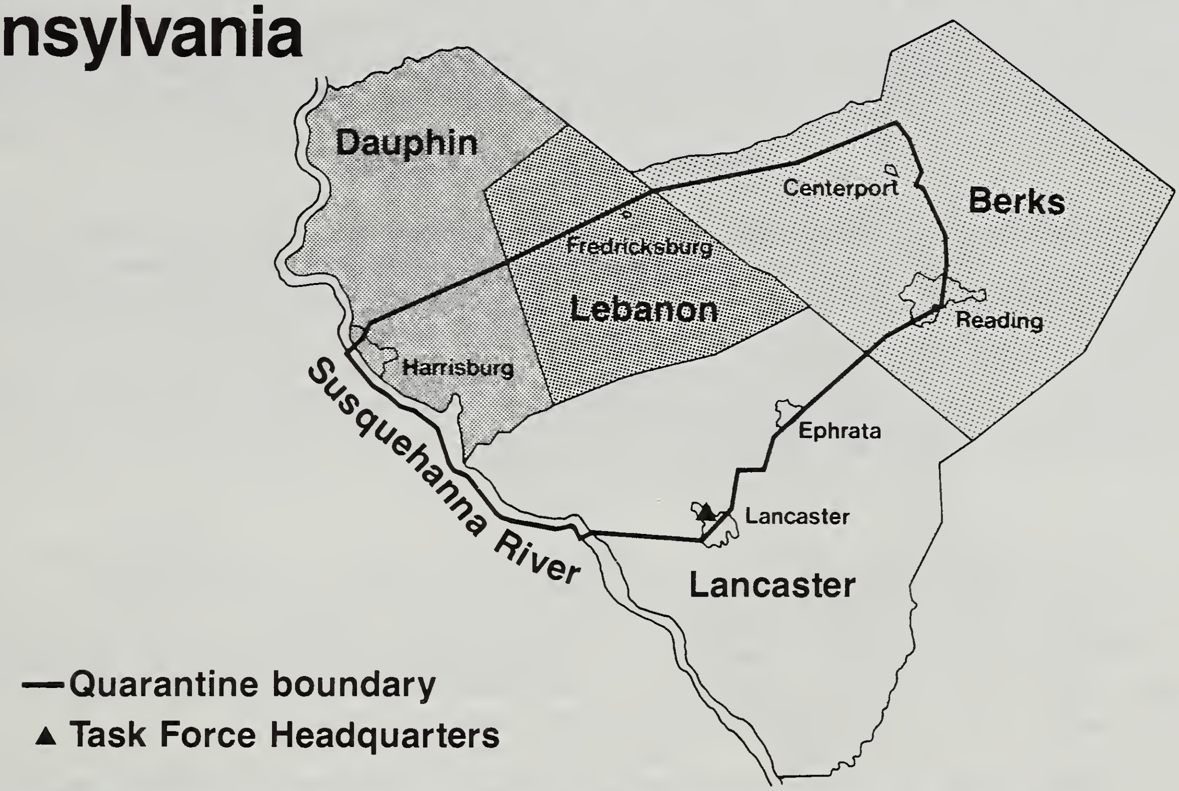
Other Trade Restrictions

JANUARY 1984: The list of countries which had placed trade restrictions on poultry and poultry products exported from the United States had doubled by mid-January. Included in this list were Canada, Switzerland, Netherlands, Japan, Argentina, Brazil, Panama, Singapore, Mexico, Italy, France, and Spain.

FEBRUARY 1984: This month's activity brought trade restrictions from four more countries: Colombia, West Germany, Peru, and the USSR. During this month, several countries added Maryland and Virginia to their banned areas in response to the notification that AI now existed in those States also. By early March, four more countries had placed restrictions on U.S. poultry exports, bringing the total count to twenty.

MAY 1984: As this month drew to a close, there was a total of 22 countries with trade restrictions or bans on poultry and poultry products exported either from the area of the AI quarantine or from the entire United States. A number

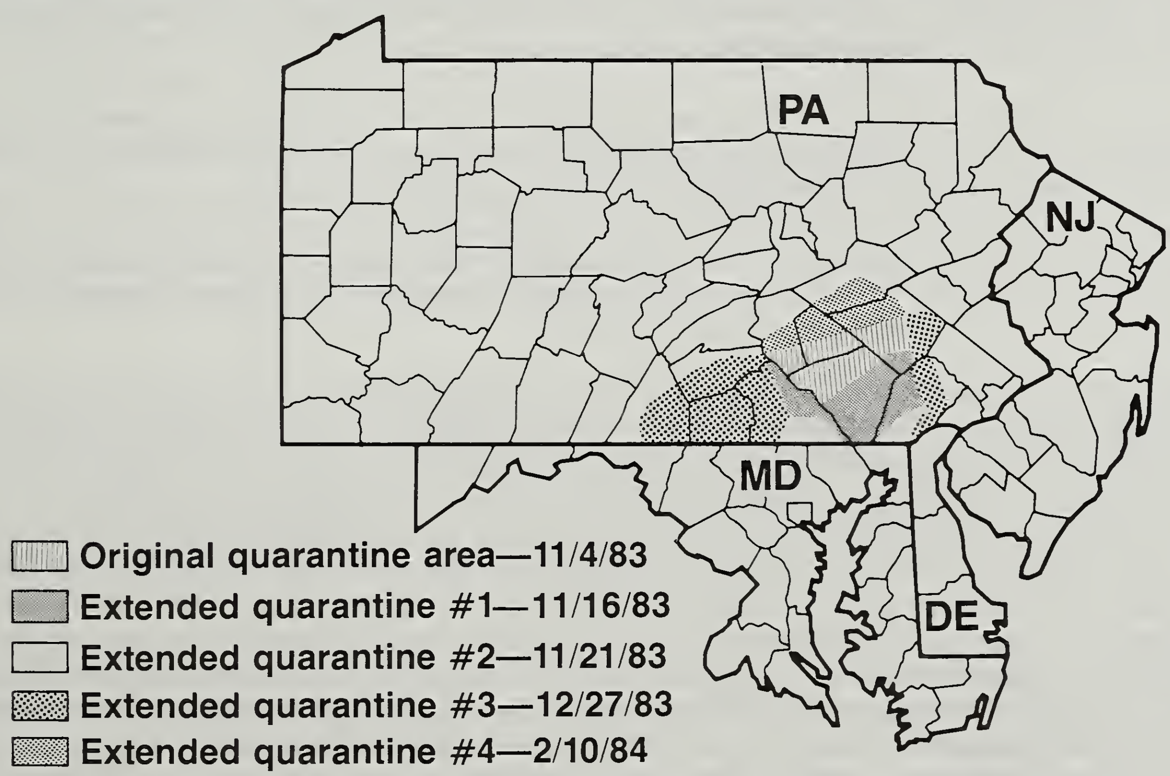
Original Quarantine: Counties Involved in Pennsylvania



The original quarantine extended over portions of three counties in southeastern Pennsylvania.

Avian Influenza

Quarantine Area in Pennsylvania



The quarantine area was expanded four times during the course of the avian influenza outbreak.

of countries began modifying their trade restrictions and reducing the area involved to those States where avian influenza actually existed.

It is unlikely that the true cost to the U.S. economy and poultry industry will ever be known. There is no doubt that there have been some shifts in marketing patterns over and above the losses actually incurred during the outbreak. The response on the international level makes it quite clear that if the United States is going to compete for a share of the world poultry market, it is going to have to remain free of the lethal or highly pathogenic forms of avian influenza.

Epidemiology of Avian Influenza

Prior to the outbreak, the bio-security measures of the poultry industry ranged from very good to very lax with the average level being closest to very lax. Security measures improved greatly during the outbreak but cannot be expected to remain high in the apparent absence of disease. Even though the materials involved are relatively inexpensive, it is very difficult to convince producers that bio-security measures pay dividends. The problem is that bio-security measures, to be effective, must be faithfully and rigorously applied. In the absence of obvious disease, the average producer will not devote the required time to such practices. Virus isolation from various samples taken by task force personnel clearly showed the virus to be easily spread by:

—vehicles	—people	—equipment
—poultry	—eggs	—egg flats
—poultry coops	—manure	—carcasses

A number of insect species sampled by task force entomologists were found to have the virus internally as well as on the surface of their bodies. As a result of the studies made on possible insect vectors, an aggressive vector control program was carried out by the task force during the entire disease control effort.

The number of flocks which become ill and the rate varied between Pennsylvania and Virginia. However, the characteristic curve is evident when the positive flocks by the first date that sickness was observed is plotted on a weekly basis.

Based on experiences with human influenza, L. J. King described the avian influenza thus:

> Once an outbreak begins, early cases appear quite suddenly, with a rapid upsurge in the number of illnesses. The attack rate is very high; that is, of all birds exposed to the disease, a very high percentage become ill with influenza. If one follows the new cases of AI by flocks infected per week and plots these out on a weekly basis, the result is an epidemiology curve.
>
> The peak of the epidemiology curve is usually preceded by three to six weeks of increasing activity and is followed by three to six weeks of decreasing activity. The period of time before and after the peak of the curve is variable, yet the general pattern of the curve is predictable (8).

Eradication efforts have two very significant effects on such curves. The peak of the curve is reduced and the duration of the time period is shortened. These effects are due to quarantine restrictions which limit spread and the systematic removal of the source of infection within the quarantine area.

It has been previously observed that during a disease outbreak, there seems to be a need on the part of some individuals to find a means of spread which cannot be controlled. In this outbreak, this need manifested itself in the conviction that avian influenza was being spread through the underground water and was being blown around by the wind. The virus was not recovered from underground water samples even when the samples were of the effluent from the landfill where most of the 62-million pounds of poultry was buried. In the case of air-borne spread, an effort was made to recover the virus from the air using a large-volume air sampler provided by the military. Except for those samples which were taken just outside infected poultry facilities, there was never any success in recovering the virus from air. The dilution factor, drying effects of the wind, and viricidal effects of light, make it unlikely that the wind will ever be shown to spread virus for any significant distance. A survey of backyard flocks completed near the end of the Poultry Watch program demonstrated no positive serology. Since these flocks were in the area where infected flocks were located, they are a good biological indicator of how unlikely it is that avian influenza can be spread by the wind. The personnel from the Southeastern Cooperative Wildlife Disease Study, Athens, GA, carried on extensive epidemiologic studies of potentially involved wildlife:

> Results of these studies suggest that wildlife such as ducks, geese, seagulls, crows, blackbirds, starlings, sparrows, pigeons, mice, and rats did not play a significant role in the spread of AI virus among farms within the quarantine zone.
>
> Although aquatic birds had influenza antibodies suggesting prior infection with viruses of the H5 subtype, their possible role in the initial outbreak in Pennsylvania is uncertain. Influenza viruses are known to circulate through free-flying aquatic birds during the spring and early summer months, when a large number of juvenile birds enter the bird population (9).

Most of the samples which were collected from wildlife sources were sent to the World Health Organization Influenza Center located at St. Jude Children's Research Hospital in Memphis, TN. At the center, extensive work was done on these samples to characterize the virus which caused the avian influenza outbreak. The results were discussed at the 1984 meeting of the United States Animal Health Association:

> The results suggest that the original avirulent virus was probably derived from influenza viruses from wild birds and that the virulent strain was derived from the avirulent strain by selective adaptation rather than by recombination or the introduction of a new virus into the population (10).

These findings would tend to support the feeling that a "waterfowl" connection does exist, and this virus or ones very much like it undoubtedly exist in the migratory waterfowl population. The link between domestic poultry and migratory waterfowl is through farm ponds. The migratory waterfowl visit the farm ponds and leave the avian influenza virus behind in their droppings to be tracked into the poultry premises.

The epidemiologic study of avian influenza has yielded several lessons," . . . the importance of divorcing the poultry industry from any association with wild migrating birds, the importance of strict premises biosecurity, and the importance of controlling the movements of dirty coops, egg flats, and/or cartons" (11).

The Typical Case

While cases of avian influenza had differences from flock to flock, many of the differences were only a matter of degree. Clinical signs which were common to most cases began to emerge within the first few weeks of the task force. A consistency in the manner of managing the avian influenza infected premises developed which can best be illustrated by following a typical case.

A typical case of avian influenza was usually reported to the task force by telephone. When a sick call came in, the following basic information was recorded: premise owner's name, address, telephone number, type and size of flock, and the number of sick birds. The reported case was then assigned to a veterinary diagnostician for investigation. A visit to the sick flock by the veterinary diagnostician consisted of a careful review of the flock history and records, as well as an examination of the birds and collection of specimens to be sent to NVSL.

The farm visit to examine the sick flock was a carefully thought out process. It was necessary for the veterinary diagnostician to physically examine the flock and come in contact with potentially infected birds. If the flock to be examined had avian influenza, the veterinarian had to assure that the disease would not be spread from the farm by the visit or diagnostic activities. If the flock was not infected with avian influenza, then all possible precautions had to be exercised to assure that the diagnostician did not bring disease to the flock. The visit was an example to the poultry industry of the biosecurity which should normally be exercised to prevent the spread of disease.

A clean vehicle, carrying an absolute minimum of supplies and equipment, was used to visit the poultry farm. The vehicle was parked in an area which was the least likely to be contaminated. Disposable protective clothing was used to cover regular clothing during the visit. The disposable protective clothing was removed following the visit and placed in plastic bags and destroyed. Any specimens or equipment taken from the farm were considered contaminated and carried in a designated "dirty" area of the car. Careful complete disinfection of boots, hands, and equipment was routine. After the farm visit, the car was washed by a local commercial car-wash.

When visiting farms for diagnosis or other reasons, AI task force members wore disposable suits and head coverings to maintain biosecurity.

The following morning, the diagnostician presented his observations and the history of the flock in a formal review before the other task force diagnosticians. As a result of these review meetings, all attending diagnosticians were kept up-to-date on the most recent findings and trends of the disease. Problem cases were discussed extensively and the plans formulated for further diagnostic workup. Some of the most significant clinical signs which might be reported included—

— sudden increase in bird mortality
— birds depressed
— decrease in food and water consumption
— central nervous system disturbances
— respiratory noise in the flock
— foot and leg swelling
— decreased egg production
— soft shell egg production

The declaration that a flock was positive for avian influenza was based on clinical, epidemiologic, and/or laboratory evidence of the disease (12). Once a flock was declared positive, preparations for depopulation were immediate. A security guard was posted at the entrance to the premises to insure proper cleaning and disinfecting of the persons, equipment, and vehicles leaving the farm. A task force appraisal team was dispatched to determine the value of the flock and begin the paperwork necessary for payment of indemnity. The indemnity paid on a flock was based on the number and type of birds in the flock.

The price of eggs to be disposed of during the depopulation of a poultry farm was determined before the appraisal using the current market quotation as reported by the Urner Barry Publishing Company. Other materials on the poultry farm which could not be readily cleaned and disinfected, such as feed and egg flats, were also appraised and removed with the chickens. The prices of these materials were determined by the actual cost to the facility as indicated by invoice. The entire appraisal process was designed to assure a uniform, authoritative fair-market value for birds and materials.

When the appraisal crew completed their work, the flock was scheduled for depopulation. The depopulation began with placing a number of large open-top steel containers near the poultry houses to receive the birds and other materials. These containers, normally used for waste disposal, are carried on special trucks which can pick up the full container from the ground and dump its contents at a disposal site. The containers were lined with plastic and covered with tarpaulins. Cylinders of carbon dioxide were placed near the containers and the gas was allowed to flow inside.

A crew collected the birds from the poultry house and placed them in the containers through an opening made by raising the tarpaulin slightly. Inside the containers, exposure to the carbon dioxide gas would immediately sedate and

euthanize the birds. When a container was full, the tarpaulin was secured firmly over the top and the contents were saturated with carbon dioxide to assure euthanasia. Trucks picked up the full containers and transported them to local landfills where the birds and other materials were buried. Cleaning and disinfecting crews sprayed disinfectant on the trucks and containers with a pressure washer before the trucks left the farm and then again before the empty trucks left the landfill. Acceptable disposal for the tons of carcasses which resulted from the depopulations was a significant problem. During the outbreak, it was necessary to bury almost all the birds and other materials in landfills because of the shallowness of the soil which overburdened the porous limestone bedrock.

Carcasses were transported to landfills by special trucks that picked up the steel containers used to collect the birds on the farms.

After depopulation, the poultry facility was treated with pesticides to control vectors such as flies, beetles, and rodents that might move the disease to other farms. The vector control treatments were left undisturbed for at least 3 days after which the owner was allowed to begin the process of cleaning and disinfecting the premises. Extensive supervision and technical advice was provided by task force C&D personnel as the premises owner first cleaned and then disinfected the facilities. Only disinfectants which had been demonstrated effective in killing avian influenza virus were approved for use. When the facilities passed C&D inspection, they were sampled in an effort to determine if all live avian influenza virus had been eliminated. After the samples were determined to be negative and a required minimum 30-day period of "down-time" had been observed, the premises were ready to be repopulated with birds.

Surveillance—Poultry Watch

The final stage in the eradication of avian influenza began when surveillance was expanded to cover the entire population of poultry in the quarantine area through a program dubbed "Poultry Watch." This program initially made use of swab samples from normal mortality birds. A shift was made to the use of blood and egg-yolk serology when the collection of these samples proved to be more efficacious.

Poultry Watch was conceived as a tool for elimination of the last traces of avian influenza and as a surveillance system to be maintained for 6 months after the lifting of the Federal/State quarantines to assure the complete success of the operation.

The Federal/State quarantines were officially lifted on October 4, 1984, and the 6-month surveillance activity of Poultry Watch concluded on April 2, 1985.

THE COST - THE BENEFITS

During the 11 months that the avian influenza task force existed, $63 million was spent, 449 flocks were involved, and over 17 million birds were depopulated to end the threat of the virus. The public funds spent in the eradication of H5N2 avian influenza virus prevented much greater losses. The losses to producers and consumers amounted to less than 10% of those which would have otherwise resulted.

During the course of the outbreak, producers had an estimated $55 million in direct losses, i.e., poultry and eggs, and further losses resulting from down-time, cleaning, and lost income. Out of the $63 million spent, the largest portion ($41.8 million) was paid directly to the producers as Federal indemnity. The Federal indemnity payment helped offset direct losses to producers. This indemnity was paid for poultry, eggs, and materials actually destroyed by the task force during the course of the outbreak.

The small drop in available poultry products drove up prices of poultry products and also increased the prices of pork and beef. The increased prices caused consumers to spend approximately $349 million more during the 6-month period beginning in November 1983. It is estimated that, if avian influenza had been allowed to spread throughout the eastern United States, producers would have lost $508 million and consumers would have lost $5.6 billion in higher food prices during the same 6-month period (14).

Actual operating expenses of the task force for personnel, and items such as travel, rent, and supplies amounted to only about one-third of the total expenditures. The job of eradicating this outbreak of avian influenza was undertaken to protect the national poultry industry valued at nearly $12 billion (15). The job was successful.

Many of the people who did the work of eradication will not receive any recognition for their efforts other than the knowledge that avian influenza has been eliminated as a present threat to the United States poultry industry. John Atwell, Deputy Administrator, Veterinary Services, expressed his appreciation of the wide involvement.

> When we accomplish a major goal or eradicate a large disease outbreak, it is easy to identify the leaders who carried much of the program direction, but difficult to identify those who did much of the work.
>
> Thus, when we give plaudits for a job well done, we fail to remember all the clerks, laboratory technicians, animal health technicians, field VMO's and a great host of others that work behind the scene or in positions in which they are not readily recognized.
>
> I want to rectify this in some small way by saying that behind every success is a large number of dedicated employees that carry forward in their own way a small but important function that, if left undone, would jeopardize an operation.
>
> Everyone in VS has an important job. It may be correcting the English in a supervisor's letter, burying chicken manure, filing claims, washing test tubes, securing facilities from theft, or processing pay vouchers. Diseases cannot be eradicated without dedication to such details.
>
> Veterinary Services and the industries we serve owe all of you, no matter what your job, a vote of thanks for a job well done (16).

Avian influenza was the most devastating and expensive poultry disease ever faced by animal health professionals in the United States. AI's eradication is a fitting end to the first century of the Bureau of Animal Industry and an auspicious beginning for the next. The story of the Bureau of Animal Industry and the organization which it has become is indeed a success story.

Economic Impact of Avian Influenza

Statistics

- **$9.6 billion nation poultry industry value**
- **17 million birds depopulated**
- **449 flocks involved**
- **$63 million in public funds spent**
- **$41.8 million in Federal indemnities**

November 1983 - September 1984

Economic Impact of Avian Influenza

Increases in Costs to Consumers

(November 1983—April 1984)

Eggs	$120 million
Broilers	$ 80 million
Turkeys	$ 13 million
Other chickens	$ 12 million
Pork	$ 60 million
Beef	$ 64 million

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CHRONOLOGY OF EVENTS

May 15, 1862. Act establishing the Department of Agriculture approved.

December 18, 1865. First act of Congress to prevent introduction of disease in imported cattle; administered by Treasury Department.

1868. John Gamgee appointed to make a study of Texas fever.

March 3, 1873. Twenty-Eight Hour Act provided for regulating interstate transportation of livestock.

1883. The Veterinary Division was established.

May 29, 1884. The Veterinary Division became the Bureau of Animal Industry in accordance with an act of Congress.

August 25, 1884. Transfer of animal quarantine stations from Treasury Department to Department of Agriculture.

1885. Isolation of the first *Salmonella* organisms.

1886. Demonstration that vaccines made from killed cultures (bacterins) protect animals against some bacterial diseases.

1887. Congress authorizes BAI to purchase and destroy diseased animals.

1887. BAI moves experiment station from Benning Rd. in Washington, D.C., to leased land at Bethesda, MD.

1888-1889. Discovery of microparasite causing tick fever and that it was transmitted by cattle ticks, through work of Cooper Curtice, Fred Kilbourne, and Theobald Smith.

1889. Discovery of cause of Texas fever and the role vectors play in spreading infectious diseases.

1890. Stephen M. Babcock perfected a test for measuring butterfat in milk.

August 30, 1890. Meat Inspection Act provided for inspection of salted pork and bacon for export and for quarantine of imported animals.

1891. *Index Catalogue of Medical and Veterinary Zoology* begun. Continued until 1985.

1891. U. S. National Parasite Collection started.

March 3, 1891. Meat Inspection Act amended to include inspection of live animals for export or for animals whose meat was intended for slaughter for interstate trade.

1891. First tuberculin test on cattle in the United States in Pennsylvania.

April 1, 1891. Following the passage of the Meat Inspection Act, the work of the Bureau was expanded and reorganized. An order of the Secretary established the following divisions: Animal Pathology, Field Investigations, Quarantine, and Inspection.

September 26, 1892. Eradication of bovine pleuropneumonia announced.

1895. BAI first uses dipping vats for cattle fever ticks on King Ranch in Texas.

1895. Discovery of differences between human and bovine tuberculosis organisms.

July 1, 1895. The Dairy Division was established in the Bureau of Animal Industry.

April 25, 1896. The Biochemic Division was established to succeed the Biochemic Laboratory established on January 1, 1890.

July 1, 1896. The Quarantine Division became a part of the Miscellaneous Division.

1898. BAI begins bacteriological studies of milk.

1900. Tuberculin test required for imported cattle.

1900. BAI purchases 50-acre tract in Bethesda, MD, for experiment station to study diseases of domestic animals.

1901. The Zoological Laboratory, established August 1, 1886, became the Zoological Division.

1902. Southern hookworm identified by Charles W. Stiles who also discovered prevalence of hookworm disease in the South and a new species of hookworm.

1903. Alexander deSchweinitz and Dr. Marion Dorset discover that hog cholera is caused by a virus.

July 1, 1903. The Miscellaneous Division was reorganized and redesignated the Quarantine Division.

1904. BAI authorized to carry out animal feeding and breeding experiments.

1905. Malta fever (brucellosis) discovered in imported goats.

1906. Poultry husbandry investigations begun at Halethorpe, MD.

1906. Inbreeding experiments with guinea pigs begun.

June 29, 1906. 28-Hour law revised providing for humane care of livestock in interstate shipment.

June 30, 1906. New Meat Inspection Act strengthened inspection to include sanitation.

1907. Dr. Marion Dorset devises branding fluid for use in meat inspection.

1907. Development of hyperimmune serum to prevent hog cholera.

February 1908. Secretary James Welson appointed a five person committee on veterinary education.

1909. BAI begins tracing tuberculous cattle and swine from slaughtering plants to farms.

1910. BAI establishes research center at Beltsville, MD.

January 1, 1910. The Animal Husbandry Office was redesignated as the Animal Husbandry Division.

1911. BAI authorizes official use of arsenical solution as dip for cattle fever ticks, following development of a practical field test for the dip.

1912. BAI begins Extension work in cooperation with the Bureau of Plant Industry.

September 1, 1912. The Inspection Division was divided into the Meat Inspection Division and the Field Inspection Division.

March 4, 1913. Virus Serum Toxin Act approved, providing for regulation of importation or interstate shipment of viruses, serums, and toxins for treatment of domestic livestock.

October 3, 1913. Tariff Act made imported meat subject to meat inspection.

1914. BAI announces discovery that trichinae in pork can be destroyed through proper refrigeration, leading to effective meat inspection control measures.

1914. First Bureau of Animal Industry film, "Cooperative Cow Testing in Vermont."

1914. Discovery of cause of brucellosis in swine.

1915. BAI researcher, Dr. Sewell Wright, launches a long-term study of genetics using guinea pigs. Principles of population genetics he developed continue to be used by scientists around the world.

1917. USDA began work on developing the Colombia breed of sheep.

March 4, 1917. Congress appropriated $75,000 for tuberculosis eradication.

May 1, 1917. The Tuberculosis Eradication Division was established.

May 1, 1917. The Tick Eradication Division was established.

1918. BAI releases film, "Charge of the Tick Brigade," the first agricultural animated cartoon and field film designed to aid an animal disease eradication campaign.

1918. Discovery of relationship between brucellosis organisms that cause the disease in cattle, swine, and goats.

1918. Proved sire breeding project begun at Beltsville, MD.

April 16, 1919. The Division of Hog Cholera Control was established to replace the Office of Hog Cholera Control, established January 1, 1916.

1919. BAI launches Dairy Herd Improvement Plan, a systematic plan to improve milk production through use of purebred sires.

July 24, 1919. Legislation approved providing for inspection of horses, and horse meats and products.

July 1, 1920. The Office of Virus Serum Control, established February 17, 1917, was given divisional status.

1921. BAI discontinued Extension work in animal and poultry husbandry.

August 15, 1921. Packers and Stockyards Act approved and the Packers and Stockyards Administration established in the Department of Agriculture.

May 1, 1922. The Quarantine Division became part of the Field Inspection Division.

1923. Mclean County, Illinois, Swine Sanitation system for control of swine parasites announced.

July 1, 1924. The Dairy Division, created in the Bureau of Animal of Industry on July 1, 1895, became the Bureau of Dairying.

1926. Targhee sheep developed.

July 1, 1926. The Bureau of Dairying was redesignated the Bureau of Dairy Industry.

1927. Voluntary inspection of poultry inaugurated by the Bureau of Animal Industry.

July 1, 1927. The Packers and Stockyards Administration was abolished as an independent agency and the work was transferred to the Bureau of Animal Industry where the Packers and Stockyards Division was established.

1929. Foot and mouth disease eradicated.

1929. Fowl plague eradicated.

1929. Development of a field test to detect pullorum disease in poultry.

May 1, 1929. The Bureau of Dairy Industry was reorganized, and its work, formerly organized by project, was realigned in the following divisions:. Dairy Cattle Breeding, Feeding, and Management Investigations; Market Milk Investigations; Dairy Herd Improvement Investigations; Dairy Manufacturing Investigations and Introduction.

1930. Dr. Jim Buck reports on use of Strain 19 vaccine to protect cattle from brucellosis.

1930's. Discovery of previously unsuspected antiparasitic properties of phenothiozine and certain hydro-carbons.

June 17, 1930. Section 306 of the Tariff Act placed an embargo on the importation of cattle, sheep, other domestic ruminants and swine, and fresh meat from any such animals from countries infected with foot-and-mouth or rinderpest diseases. Imported meat unfit for human food was to be destroyed.

1931. BAI announces stained-antigen, whole-blood test for pullorum disease.

1934. State-Federal efforts to control and eradicate brucellosis begin as part of a cattle reduction program associated with a severe drought.

1934. Department of Agriculture and Iowa Agricultural Experiment Station imported Danish hogs for cross breeding to develop meat-type hogs.

1934. Glanders, a disease of horses, eradicated.

June 1, 1934. The Division of Tick Eradication and Special Diseases was formed by the consolidation of the Tick Eradication Division with the Division of Hog Cholera Control.

1935. Development of crystal violet-killed vaccine to prevent hog cholera.

1935. National Poultry Improvement Plan begins, with elimination of pullorum disease a major goal.

June 29, 1935. Bankhead-Jones Act, approved providing for expansion of research.

October 1, 1935. The Division of Dairy Manufacturing Investigations and Introduction was abolished and its activities were transferred to the Division of Dairy Research Laboratories.

May 1, 1936. The Division of Animal Nutrition was established to study problems of feeding and nutrition in livestock.

November 4, 1936. The establishment of the Division of Physiology and Nutrition, BDI, was approved.

October 16, 1938. After the transfer of the enforcement of the Packers and Stockyards Act to the new marketing and regulatory agency, other functions of the former Packers and Stockyards Division relating to interstate transportation of livestock and the administration of livestock transportation and quarantine laws were continued by the newly established Interstate Inspection Division.

1939. BAI begins supplying a standardized brucella antigen to State diagnostic laboratories.

June 13, 1940. The Biochemic Division was abolished and its functions were divided between the Pathological and the Animal Nutrition Divisions.

1942. Dourine eradicated in the United States.

February 23, 1942. The Bureau of Dairy Industry and the Bureau of Animal Industry became part of the Agricultural Research Administration, established to coordinate work of the scientific bureaus.

June 23, 1942. The Animal Nutrition Division and the Animal Husbandry Division were combined and designated the Division of Animal Husbandry.

December 5, 1942. In accordance with Executive Order 9280, the enforcement of the Meat Inspection Act, the 28-Hour Law, and related activities were transferred from the Bureau of Animal Industry to the Food Distribution Administration.

1943. Cattle tick fever eradicated in the United States.

August 30, 1943. The Divisions of Interstate Inspection and Tick Eradication and Special Diseases were merged administratively and continued as the Interstate Inspection Division.

1944. Beltsville small white turkey developed.

February 21, 1944. The consolidation of the Division of Market Milk Investigations with the Division of Dairy Research Laboratories was approved.

August 14, 1946. Research and Marketing Act approved providing for expanded research.

October 1, 1946. Enforcement of the Meat Inspection Act, the 28-Hour Law, and related administrative functions were transferred from the Production and Marketing Administration to the Bureau of Animal Industry, August 21, 1946, and were continued by the Meat Inspection Division and the Interstate Division, respectively.

November 20, 1946. The Animal Foods Inspection Division was created to inspect, certify, and identify canned food for cats, dogs, foxes, and other meat-eating animals.

April 22, 1947. The establishment of the Interstate Inspection, BAI, and the Inspection and Quarantine Divisions was approved. The former represented a consolidation of functions of the former Interstate Inspection Division and the Field Inspection Division relating to animal disease control and eradication and the work transferred from the Production and Marketing Administration relative to administration of the 28-Hour Law. The Inspection and Quarantine Division was to have jurisdiction over other functions of the former Field Inspection Division and functional responsibility for the Bureau in foreign disease control and eradication programs.

1949. Discovery of variant hog cholera virus.

July 14, 1950. The Tuberculosis Eradication Division, BAI, was redesignated the Brucellosis and Tuberculosis Eradication Division.

1951. Development of practical tests to differentiate between foot-and-mouth disease, vesicular stomatitis, and vesicular exanthema.

1952. Secretary of Agriculture announces selection of Plum Island, NY, as site of laboratory for foreign animal disease research and diagnosis.

1952. Discovery of the cause of hyperkeratosis of cattle.

1953. Identification of vibriosis as a cause of infertility in cattle.

November 2, 1953. Prior to its abolition, the Bureau of Dairy Industry was composed of the following divisions: Dairy Herd Improvement Investigations; Dairy Cattle Breeding, Feeding, and Management; Nutrition and Physiology; and Dairy Products Research Laboratories.

November 2, 1953. Prior to its abolition, the Bureau of Animal Industry consisted of the following divisions: Animal Husbandry; Pathological; Zoological; Meat Inspection; Animal Foods Inspection; Inspection and Quarantine; Virus-Serum Control; Brucellosis and Tuberculosis Eradication; and Interstate Inspection.

November 2, 1953. The Agricultural Research Service established to administer research. Scientific bureaus were abolished and functions transferred from other agencies.

1954. Research on foreign animal diseases begins at Plum Island Animal Laboratory.

January 2, 1954. The nonregulatory functions of the former Bureau of Dairy Industry were assigned to the Dairy Husbandry Research Branch and the regulatory to the Meat Inspection Branch.

1955. Identification of a new fowl cholera organism.

1957. USDA conducts eight radiological defense training meetings throughout the United States for Federal, State and local veterinarians.

1957. Development of vaccines to prevent fowl cholera.

August 26, 1957. Poultry Products Inspection Act provided for compulsory inspection of poultry sold in interstate commerce.

1958. Discovery of the cause of rhinotracheitis of cattle.

August 28, 1958. Humane Slaughter Act approved.

1959. Isolation of a virus that causes the shipping fever complex.

1959. Screwworms eradicated in southeastern United States.

1959. Vesicular exanthema eradicated.

1960. After 24 years of study, mycoplasma gallisepticum identified as the causitive agent of chronic respiratory disease of chickens and infectious sinusitis of turkeys.

1961. USDA consolidates domestic animal health research and diagnostic work at new facility at Ames, IA.

July 2, 1962. Amendment to act of March 3, 1905 (33 Stat 1264) expanded coverage to any animals and authorized issuance of regulations to prohibit movement into the United States of any animals affected with, exposed to, or vaccinated against disease, when necessary to protect the domestic livestock industry.

1965. Development of a rapid test for hog cholera.

February 8, 1965. Meat Inspection functions were transferred from the Agricultural Research Service to the newly designated Consumer and Marketing Service.

1966. Congress passes Laboratory Animal Welfare Act, giving USDA authority to require humane care for dogs and cats used in research and to prevent petnapping.

1966. Screwworms eradicated in southwestern United States.

1966-1985. Development of *in vitro* culture methods for protozoan and helminth parasites of major economic importance in livestock and poultry.

December 15, 1967. Wholesome Meat Act approved including major revision of 1906 act.

1968. USDA sends veterinarians to assist Great Britain with foot-and-mouth disease outbreak.

1968. Development of the complement-fixation and card tests for the diagnosis of anaplasmosis.

August 18, 1968. Wholesome Poultry Products Act approved extending to poultry inspection many aspects of the meat inspection act approved in 1967.

1970. Development of pooled sample technique for the detection of trichinae in commercially slaughtered hogs.

December 29, 1970. Egg Products Inspection Act approved.

1971. Venezuelan equine encephalomyelitis eradicated.

1971. Discovery, development, and licensing of a vaccine for Marek's disease of chickens.

October 31, 1971. Animal and Plant Health Service established to administer plant and animal regulatory and disease control programs.

1972. USDA establishes five "regional emergency animal disease eradication organizations" (READEO's) to combat outbreaks of foreign animal diseases.

1972. Development of the capability of identifying parasites in cross-sections of host tissues.

April 2, 1972. Meat inspection work transferred from Consumer and Marketing Service to the redesignated Animal and Plant Health Inspection Service.

1972-1982. Discovery of the life cycle, epidemiology, pathogenicity, and economic importance of the wide-spread parasite of livestock, *Sarcocystis fusiformis*.

1973. Sheep scabies eradicated.

1974. Exotic Newcastle disease eradicated.

1975. Discovery that differences in the spacing of longitudinal ridges in the cuticle of some nematode parasites of vertibrates make possible the identification of the female worms to species.

1976. Development of a test to identify cattle infected with leukemia virus.

April 27, 1976. Animal Welfare Act amended to provide for humane air transportation of certain animals.

1978. USDA licenses first killed virus vaccine for pseudorabies in swine.

1978. Hog cholera eradicated.

October 10, 1978. Humane Slaughter Act approved.

1980. Congress passes the Swine Health Protection Act, which provides for proper treatment of garbage fed to swine.

1981. Identification of a parvovirus as an agent of infertility in U.S. swine and development of a vaccine to prevent the disease.

1982. Discovery of a sub-unit vaccine for foot-and-mouth disease—the first vaccine through gene splicing for any disease of man or animals.

1982. USDA establishes joint foot-and-mouth disease vaccine bank with Mexico and Canada.

1982. Congress authorizes firearms for tick inspectors.

1983. USDA begins pilot projects in Ohio and Tennessee on a "national animal disease detection system" (NADDS).

1983. Recombinant vaccine against coccidioses of poultry developed.

1984. Insertion of human growth gene in swine.

1984. Eradication of outbreak of highly pathogenic avian influenza in Pennsylvania and Virginia.